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Revision 2

Data Quality Objectives Summary Report for Operable Unit 7-08 Post-Record of Decision Sampling

June 2005

Idaho Cleanup Project

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Revision 2
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Data Quality Objectives Summary Report for Operable Unit 7-08 Post-Record of Decision Sampling

June 2005

Idaho Cleanup Project
Idaho Falls, Idaho 83415

Prepared for the
U.S. Department of Energy
Assistant Secretary for Environmental Management
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ABSTRACT

This data quality objective summary report supports decision-making activities for Operable Unit 7-08 remediation of organic contamination in the vadose zone beneath the Radioactive Waste Management Complex. Operable Unit 7-08 extends from the land surface to the top of the Snake River Plain Aquifer approximately 177 m (580 ft) below ground surface outside the disposal pits and trenches within the Subsurface Disposal Area. The vadose zone contains volatile organic compounds primarily in the form of organic vapors that have migrated from the buried waste in the Subsurface Disposal Area pits.

The format of this report is consistent with U.S. Environmental Protection Agency guidance for developing data quality objectives. This revision to the original data quality objectives summary report published in 2000 contains an updated vapor monitoring well list, an updated vapor extraction well list that expands the VVET system extraction capability into the deep vadose zone, new preliminary remediation goals (PRGs) for each PRG zone defined in the data quality objective report, and a discussion of the Accelerated Retrieval Project and its potential impact on Operable Unit 7-08 and the volatile organic compound source.

CONTENTS

FIGURES

TABLES

ACRONYMS

ABRA	Ancillary Basis for Risk Analysis
ARAR	applicable or relevant and appropriate requirement
ARP	Accelerated Retrieval Project
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CIDRA	Contaminant Inventory Database for Risk Assessment
COC	contaminant of concern
COPC	contaminant of potential concern
CUSUM	Cumulative Sum
DEQ	(Idaho) Department of Environmental Quality
DOE	U.S. Department of Energy
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
FFA/CO	Federal Facility Agreement and Consent Order
GC	gas chromatography
GC/MS	gas chromatography/mass spectrometry
HDT	historical data task
INL	Idaho National Laboratory
MCL	maximum contaminant level
NTCRA	non-time Critical Removal Action
OCVZ	organic contamination in the vadose zone
OU	operable unit
PCE	tetrachloroethene
PRG	preliminary remediation goal
PSQ	principal study question
RAO	remedial action objective

RFP	Rocky Flats Plant
RG	remediation goal
RI/FS	remedial investigation/feasibility study
ROD	record of decision
RPD	relative percent difference
RWMC	Radioactive Waste Management Complex
SDA	Subsurface Disposal Area
SRPA	Snake River Plain Aquifer
TBD	to be determined
TCA	1,1,1-trichloroethane
TCE	trichloroethene
TRU	transuranic
TSA	Transuranic Storage Area
UCL	upper confidence level
VOC	volatile organic compound
VVET	vapor vacuum extraction with treatment
WAG	waste area group
WILD	Waste Inventory Location Database
WIPP	Waste Isolation Pilot Plant

Data Quality Objectives Summary Report for Operable Unit 7-08 Post-Record of Decision Sampling

This data quality objective (DQO) summary report supports decision-making activities for Operable Unit (OU) 7-08 remediation of organic contamination in the vadose zone (OCVZ) beneath the Radioactive Waste Management Complex (RWMC). Operable Unit 7-08 extends from the land surface to the top of the Snake River Plain Aquifer (SRPA) approximately 177 m (580 ft) below ground surface outside the disposal pits and trenches within the Subsurface Disposal Area (SDA). The vadose zone contains volatile organic compounds (VOCs) primarily in the form of organic vapors that have migrated from the buried waste in the SDA pits.

Operable Unit 7-08 is the designation recognized under the *Federal Facility Agreement and Consent Order for the Idaho National Engineering Laboratory* (FFA/CO) (DOE-ID 1991) and the "Comprehensive Environmental Response Compensation and Liability Act of 1980 (CERCLA/Superfund)" (42 USC § 9601 et seq.) for OCVZ remediation beneath the RWMC, which contains the SDA. The remediation is being performed in accordance with the *Record of Decision: Declaration for Organic Contamination in the Vadose Zone Operable Unit 7-08, Idaho National Engineering Laboratory, Radioactive Waste Management Complex, Subsurface Disposal Area* (the ROD) signed in 1994 (DOE-ID 1994).

The original OU 7-08 DQO report, *Data Quality Objectives Summary Report for the Operable Unit 7-08 Post-ROD Sampling* (Bauer and Ovink 2000), was published in 2000. Revision 1 published in 2002 (INEEL 2002) presented: (1) an updated vapor monitoring well list and sampling schedule, (2) a revised organic contaminant inventory for the SDA (Miller and Varvel 2001; Varvel 2001), and (3) information from recent shallow soil gas surveys (Housley, Sondrup, and Varvel 2002).

This revision of the OU 7-08 DQO report, Revision 2, contains several new or updated items including: (1) an updated vapor monitoring well list, (2) an updated vapor extraction well list which expands the vapor vacuum extraction with treatment (VVET) system extraction capability into the deep vadose zone, (3) new preliminary remediation goals (PRGs) for each PRG zone defined in the DQO report, and (4) a discussion of the Accelerated Retrieval Project (ARP) and its potential impact on OU 7-08 and the VOC source.

The organization of this report is consistent with U.S. Environmental Protection Agency (EPA) guidance for developing DQOs (EPA 1994). The major steps involved in the DQO development process are described in Sections 1 through 7. Trending analyses performed to develop the DQO decision statements (see Section 2) are discussed in Appendix A; control charts used to analyze data are provided in Appendix B; and the methodology for determining PRGs is presented in Appendix C.

1. STEP 1—STATE THE PROBLEM

The objective of DQO Step 1 is to use the information gathered from the DQO scoping process, as well as other relevant information, to clearly and concisely state the problem to be resolved. Section 1 contains much of the background information used to arrive at the problem statement contained in Section 1.11.3.

1.1 Introduction

The 1994 OU 7-08 ROD (DOE-ID 1994) summarized the site assessment and identified the selected remedy: extraction and destruction of the organic contaminants from the vadose zone beneath and in the immediate vicinity of the RWMC. In addition, the selected remedy specified in the ROD includes monitoring of the vadose zone vapor and the SRPA. The general objective of the selected remedy is reducing the risks to human health and the environment associated with organic contaminants present in the vadose zone and preventing federal and state drinking water standards from being exceeded after the 100-year institutional control period, as defined in U.S. Department of Energy (DOE) Manual 435.1-1, "Radioactive Waste Management Manual."

The major components of the selected remedy include the following:

- Installing and operating five vapor extraction wells (in addition to an existing vapor extraction well) at the RWMC as part of a first-phase effort to extract organic contaminant vapors from the vadose zone. The selected remedy includes options to expand the number of vapor extraction wells for potential second and third phases.
- Installing and operating off-gas treatment systems to destroy the organic contaminants present in the vapor removed by the extraction wells. Catalytic oxidation or an equally effective organic contaminant destruction technology was specified for off-gas treatment.
- Adding soil vapor monitoring wells to monitor performance of the vapor extraction wells and verifying the attainment of remedial action objectives (RAOs).

For cost estimation purposes, it was assumed the remedial action would occur in three phases, with each phase being 2 years in duration. The ROD stated that the actual duration of each phase would depend on elements such as equipment procurement and installation that may be involved with each potential phase transition. In addition, organic waste remaining in the pits could extend the timeframe required to achieve RAOs using the selected remedy because the remaining organic waste could act as a long-term source of organic contamination in the vadose zone.

Phase I operations began in January 1996 and continued through December 1997. Phase II operations began in January 1998 and are expected to continue until active extraction is no longer required to ensure that the RAOs will be met. Project life cycle planning assumes that the source of the organic contamination will be eliminated or reduced to the point where active extraction within the SDA will not be required beyond 2018. This estimate is based on the following assumptions:

- The OU 7-13/14 ROD will be finalized in 2008.
- The selected remedy for OU 7-13/14 will be implemented in 2010.
- The selected remedy for OU 7-13/14 will reduce or eliminate the source of the organic contamination by 2012.
- Once the source of the organic contamination is reduced or eliminated, no more than 7 years (i.e., 2012 through 2018) will be required to extract and treat organic vapors remaining in the vadose zone. Measured vapor concentrations must satisfy the conditions required for shutdown of active extraction as specified in this report.

Once the decision has been reached to shut down active extraction, the remedial action will transition into Phase III. During Phase III, a compliance verification period will be initiated. Sampling during the compliance verification phase will provide the information necessary to decide if the system needs to be restarted or if the system can be shut down, thereby concluding the remedial action and initiating the long-term monitoring phase. The project assumes a minimum of 1 year for compliance verification (i.e., 2019); therefore, Phase III could be completed in a minimum timeframe of 1 year, but Phase III is anticipated to continue for at least 4 years (i.e., 2022). The long-term monitoring phase is initiated after the remedial action is complete and will be funded by the Long-Term Stewardship Program. During the long-term monitoring phase, the VVET systems remain shutdown, and vapor monitoring is conducted at a lower frequency than during operations or compliance verification periods. The monitoring periods are discussed further in Section 1.6.6.1.

1.2 Project Objectives

The project-specific data quality objective is to:

- Identify the environmental measurements necessary to determine when extraction and treatment can be terminated within the 100-year institutional control period.

This DQO results in developing a sampling design that satisfies this project objective. The OCVZ sampling and analysis plan will delineate the sampling design in a field-usable document.

1.3 Project Assumptions

Several key assumptions have been identified for this project and are listed below.

- Funding will be available to complete the planning exercises, including preparation or updating of the DQOs, field sampling plan, and the sampling and analysis planned in these documents.

- The current VOC fate and transport model may be modified or recalibrated as more data become available. The model is a predictive tool, the results of which will serve as the basis for assessing compliance with RAOs after completion of the 100-year institutional control period. Groundwater monitoring results obtained before shutdown of the VVET units will be used as inputs. Groundwater monitoring results obtained after shutdown of the VVET units will be used to confirm fate and transport model predictions. The treatment system will be evaluated at periodic intervals to determine the need for continued operations.

- The VVET system will be shut down periodically to evaluate system operations and measure VOC rebound concentrations in the vadose zone.

- Uncertainty of carbon tetrachloride (CCl_4) in Rocky Flats 743-series sludge[a] has been addressed most recently in *Reconstructing the Past Disposal of 743-Series Waste in the Subsurface Disposal Area for Operable Unit 7-08, Organic Contamination in the Vadose Zone* (Miller and Varvel 2005). The amount of CCl_4 buried in the SDA is estimated in the report to be as much as 7.9E+05 kg. The total amount of VOCs in 743-series sludge is estimated to be 1.1E+06 kg. Varvel (2005) estimated the non-CCl_4 fraction of VOCs to include 9.9E+04 kg tetrachloroethene (PCE), 8.9E+04 kg trichloroethene (TCE), and 8.2E+04 kg 1,1,1-trichloroethane (TCA). Section 1.6.3 contains a discussion of the VOC inventory.

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a. The waste is called 743-series waste because it was processed into sludge in Rocky Flats Plant (RFP) Building 774 and was later coded at the Idaho National Laboratory (INL) as Content Code 3 organic waste to distinguish it from different types of waste from RFP Building 774 shipped to the INL. The 743-series sludge was sent to the INL from the Rocky Flats Plant, which is located 26 km (16 mi) northwest of Denver. In the mid-1990s, the plant was renamed the Rocky Flats Environmental Technology Site. In the late 1990s, it was again renamed, to its present name, the Rocky Flats Plant Closure Project.

1.4 Project Issues

1.4.1 Global Issues

As part of the original DQO scoping process conducted in 2000, the following technical issues could not be resolved and, therefore, were identified as global issues for the OCVZ DQO:

- The selected OCVZ remedy does not include removing or treating the buried waste from the SDA. The remaining buried waste could extend the time required to achieve RAOs using the selected remedy because the remaining organic waste could act as a long-term source of vadose zone organic contamination.

- The vadose zone PRGs published in the OU 7-08 ROD (DOE-ID 1994) were developed using the PORFLOW model (Runchal and Sagar 1990). A general consensus existed among OCVZ decision-makers and project personnel that the PRGs may not be protective of the groundwater under the SDA because they only consider the presence of a shallow (less than a 73-m [240-ft] depth) contaminant plume. Modeling results obtained using the TETRAD model predict that the portion of the plume below the 73-m (240-ft) depth is sufficient to cause groundwater concentrations to exceed maximum contaminant levels (MCLs) after the 100-year institutional control period (Sondrup 1998).

- Contaminant migration patterns and modeling results potentially could be affected by uncertainties in the hydrology affecting the vadose zone under the SDA. This item has several subsets:

  - Spreading area water and perched water potentially could affect contaminant migration patterns and modeling results. These potential effects are neither well understood nor have they been included in the TETRAD vapor phase modeling to date. OU 7-13/14 recently attempted to simulate potential impacts from the spreading areas on dissolved phase contaminant migration (Holdren et al. 2002), and found water from the spreading areas coupled with the effect of a low-permeability zone in the aquifer may dilute aquifer concentrations of contaminants that migrate in strictly a dissolved phase. In the model however, water from spreading areas did not migrate beyond the SDA boundary.

  - Organic contaminants in the vadose zone potentially could degrade. This potential has not been included in the modeling performed to date but may be added if additional information becomes available.

- The OU 7-08 ROD addressed OCVZ as separate from the SDA. The OU 7-08 ROD is binding, but it is necessary for OCVZ and OU 7-13/14 to coordinate activities because remediation of the VOC source waste affects the duration of active vapor extraction.

1.4.2 Project-Specific Technical Issues and Resolutions

Several project technical issues were identified in the original DQO effort. Although most of the original issues remain valid, some are outdated and have been resolved by new or updated information.

The absence of specified compliance points in the OU 7-08 ROD places a requirement on the DQO process to develop compliance points that will meet the intent of the ROD. The compliance point is discussed in Section 1.6.8.

- The TETRAD model may need to be updated, on the basis of new characterization or monitoring data, to make it suitable for predictions in the 100-year timeframe. At the time of the original DQO scoping effort, the project was already proceeding with a deep monitoring well to obtain vapor data from below the 73-m (240-ft) C-D interbed and a well to monitor groundwater within the SDA boundary. Since Revision 1 of this DQO report, several more deep vadose zone vapor monitoring wells have been drilled. A complete list of extraction and monitoring wells is listed in Section 7.4.

- The original PRG values in the OU 7-08 ROD were developed using the PORFLOW model. New PRG values have been developed using the TETRAD model in association with input from the Idaho Department of Environmental Quality (DEQ) and EPA. Satisfaction of the RAOs will not be based solely on the use of PRGs. Additional discussions are provided in Section 1.6.7 and in Step 5.

- Modeling suggests that groundwater may become contaminated by low concentrations of organic vapors (Sondrup 1998). Therefore, it is critical to protect the deep vadose zone from additional organic contamination. Vapor-phase data from below the 73-m (240-ft) C-D interbed is essential for input into the TETRAD model. Since Revision 1 of the DQO (INEEL 2002), deep vadose zone vapor monitoring wells have been drilled and sampled. The data is being used for model development and will be used for comparison to PRGs.

- One of the issues in the original DQO is that the project may need to consider expanding VVET system operation to the vadose zone below the 73-m (240-ft) C-D interbed to remediate the contaminant plume below that depth. This evaluation will need to consider the low vapor concentration present in that zone from a cost-benefit standpoint and the potential for the system to draw the vapor plume into the deep zone. Since Revision 0 of this DQO report, six new wells have been constructed with extraction and monitoring capabilities below the 73-m (240-ft) C-D interbed. Additional shallow and intermediate-depth extraction wells have also been added. A complete list of extraction and monitoring wells is listed in Section 7.4.

1.5 References

Revision 0 of the OU 7-08 DQO report contains a list of all of the documents that were reviewed as part of the original scoping process to develop the DQO. Many of those documents were data reports containing data that has since been compiled and included in more recent and comprehensive reports or databases. Table 1-1 contains an updated list of the references considered most pertinent to the OU 7-08 DQO.

Table 1-1. Updated reference list reviewed as part of the DQO process.

- *Record of Decision: Declaration for Organic Contamination in the Vadose Zone Operable Unit 7-08, Idaho National Engineering and Environmental Laboratory, Radioactive Waste Management Complex, Subsurface Disposal Area* (DOE-ID 1994)

- *Remedial Investigation/Feasibility Study Report for the Organic Contamination in the Vadose Zone-Operable Unit 7-08 at the Idaho National Engineering Laboratory* (Duncan, Troutman, and Sondrup 1993)

- *Preliminary Modeling of VOC Transport for Operable Unit 7-08, Evaluation of Increased Carbon Tetrachloride Inventory* (Sondrup 1998)

Table 1-1. (continued).

- *Reconstructing Past Disposal of 743-Series Waste in the Subsurface Disposal Area for Operable Unit 7-08, Organic Contamination in the Vadose Zone* (Miller and Varvel 2001)

- *Ancillary Basis for Risk Analysis of the Subsurface Disposal Area* (Holdren, Becker, Hampton, Koeppen, Magnuson, Meyer, Olson, and Sondrup 2002)

- *Interim Remedial Action Report for the OU 7-08 Organic Contamination in the Vadose Zone Project* (Sondrup, McMurtrey, and Harvego 2003)

- *Fiscal Year 2004 Environmental Monitoring Report for the Radioactive Waste Management Complex* (Koeppen, Olson, Parsons, Plummer, Ritter, and Sondrup 2005)

- *Environmental and Operational End-Year Data Report for the OU 7-08 Organic Contamination in the Vadose Zone Project – 2004* (Housley 2005)

- *Estimating Carbon Tetrachloride and Total Volatile Organic Compound Mass Remaining in the Subsurface Disposal Area Pits* (Sondrup, Miller, Seabury, and Josten 2004)

1.6 Site Background Information

1.6.1 Site Description

The Idaho National Laboratory (INL) is a government-owned reservation managed by the DOE. The eastern boundary of the INL is located 52 km (32 mi) west of Idaho Falls, Idaho. The INL Site occupies approximately 2,305 km^2 (890 mi^2) of the northwestern portion of the Eastern Snake River Plain in southeast Idaho. The focus of this DQO summary report is the RWMC, which is located in the southwestern quadrant of the INL. The majority of the contamination is within the subsurface underlying the RWMC and is primarily organic solvents. The highest contamination concentrations are found immediately beneath the SDA, an area with several disposal pits and trenches previously used for the disposal of organic and other hazardous and radioactive waste. The SDA is a 39-ha (97-acre) area located within the RWMC. The RWMC encompasses 71 ha (177 acres) and consists of the SDA, the Transuranic Storage Area (TSA), and an administrative and operations area. Maps showing the locations of the RWMC at the INL and the SDA and TSA at the RWMC are provided in Figures 1-1 and 1-2.

The INL property is a volcanic plateau primarily composed of volcanic rocks and relatively thin sedimentary interbeds. The layers of basalt immediately beneath the RWMC are relatively flat and covered by 6.1 to 9.1 m (20 to 30 ft) of alluvium.

The depth to the SRPA underlying the INL varies from 61 m (200 ft) in the northern portion to 274 m (900 ft) in the southern portion. The depth to the SRPA at the RWMC is approximately 177 m (580 ft). Flow of the aquifer in this region is generally to the south-southwest. Trace quantities of organic contaminants (non-detect to 8 ppb) from the RWMC have been detected in the aquifer.

The INL has semidesert characteristics with hot summers and cold winters. Normal annual precipitation is 17.5 cm (9.1 in.) per year with estimated evapotranspiration of 15.2 to 22.9 cm (6 to 9 in.) per year. The major surface water feature present in the southern portion of the INL is the Big Lost River, approximately 2.4 km (1.5 mi) northwest of the RWMC; however, this river is typically dry because of irrigation diversions upstream. Surface water is present at the RWMC only during and following periods of heavy rainfall and snowmelt, generally from January through April.

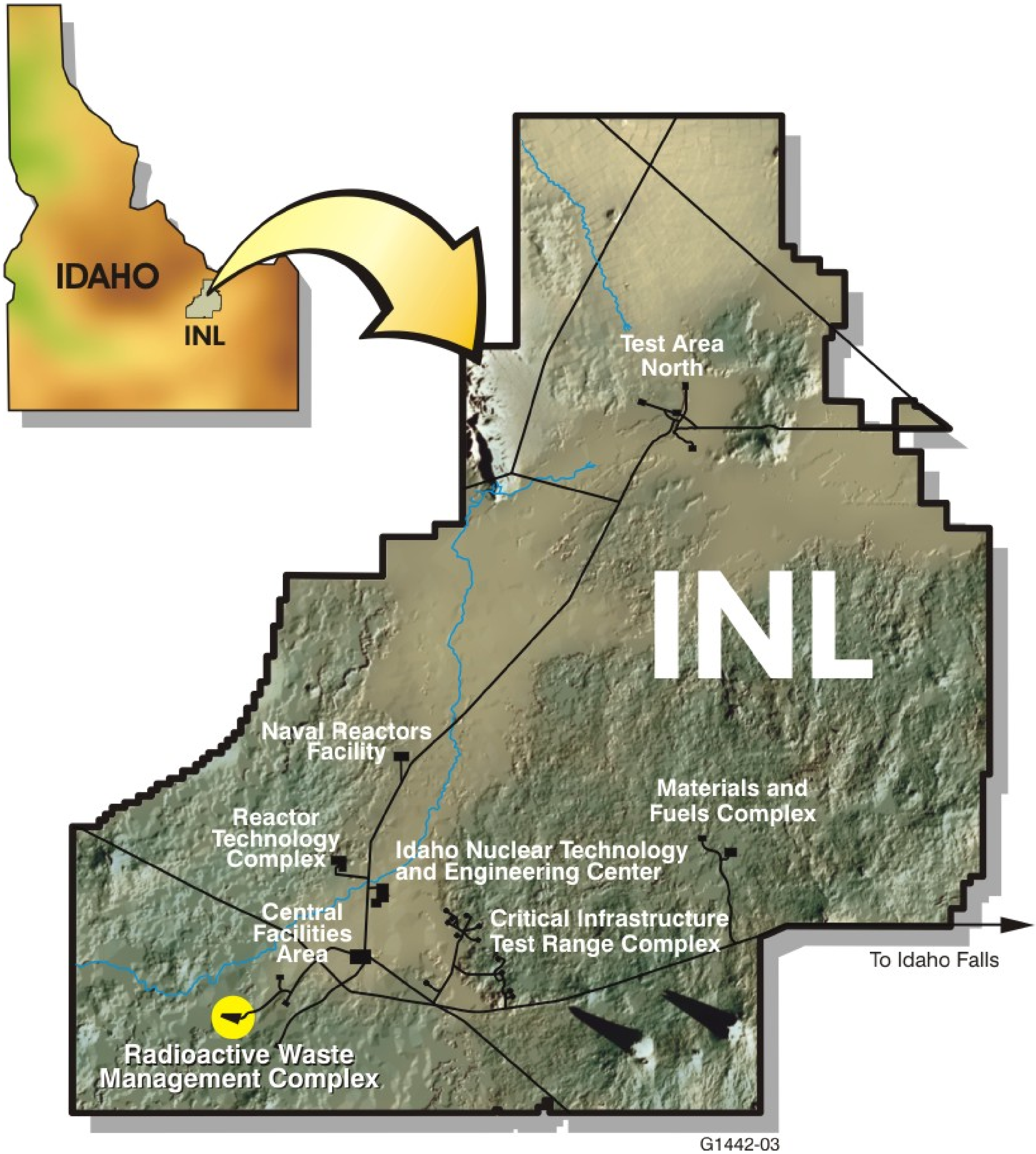

Figure 1-1. Map of the Idaho National Laboratory Site showing the location of the Radioactive Waste Management Complex.

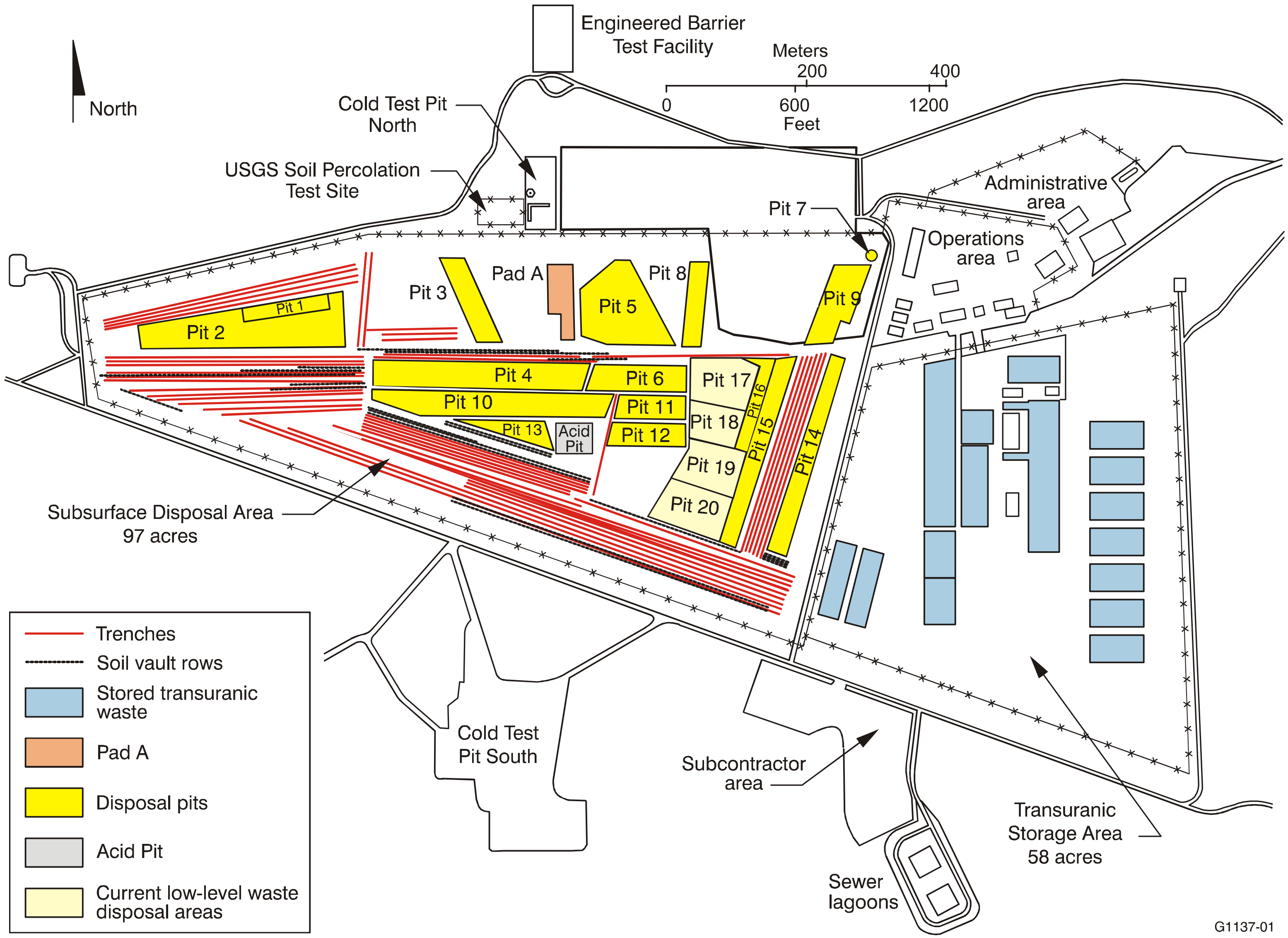

Figure 1-2. Map of the Radioactive Waste Management Complex.

To minimize the potential for surface water to flow onto the RWMC during periods of high surface water run-off, water is diverted from the RWMC via spreading areas and associated diversion channels, located to the west and south of the RWMC. To further enhance surface water diversion from disposal pits and trenches, berms have been constructed immediately around the SDA. Other surface water features include small, internally drained basins and local drainage canals that carry storm and snowmelt water away from the RWMC.

1.6.2 Site History

The RWMC was established in 1952 as a disposal site for solid, low-level radioactive waste generated by INL operations. The SDA contains hazardous substances including radioactive waste and organic waste in underground pits, trenches, soil vault rows, and Pad A, an aboveground pad. Transuranic (TRU) waste[b] was disposed of in the SDA from 1952 to 1970 and was received from the Rocky Flats Plant (RFP) for disposal in the SDA from 1954 to 1970. When the burial of TRU waste was discontinued in the SDA, the TSA was established to provide interim storage of the waste in containers on asphalt pads. The TSA accepted TRU waste from off-Site generators for storage from 1970 through 1988. Transuranic waste generated at the INL is still accepted for storage at the TSA.

Organic contaminants are present in the subsurface fractured basalt and sedimentary interbeds (i.e., the vadose zone) beneath and within the immediate vicinity of the RWMC, above the SRPA. The presence of organic contaminants in the vadose zone is a result of the burial and presumed breach of containerized organic Rocky Flats Plant waste in the SDA. Pits 4, 5, 6, 9, and 10 have been identified as receiving the majority of organic waste, which was mixed with calcium silicate to reduce free liquids and form a grease or paste-like material before being placed in containers and sent from the Rocky Flats Plant to the INL for disposal in the pits. Also, Pit 2 received an unknown quantity of organic waste before 1966, and the acid pit may have received organic waste during past operations.

A Consent Order and Compliance Agreement was entered into between DOE and the EPA pursuant to the Resource Conservation and Recovery Act Section 3008(h) in August 1987 (DOE-ID 1987). The Consent Order and Compliance Agreement required DOE to conduct an initial assessment and screening of all solid waste and hazardous waste disposal units at the INL and establish a process for conducting any necessary corrective actions.

On July 14, 1989, the INL proposed for listing on the National Priorities List (54 FR 29820). The EPA proposed the listing under the authority granted EPA by CERCLA as amended by the Superfund Amendments and Reauthorization Act of 1986 (Public Law 99-499). The INL was added to the list on November 21, 1989 (54 FR 48184).

Because the INL is on the National Priorities List, U.S. Department of Energy Idaho Operations Office, the State of Idaho, and EPA entered into the FFA/CO on December 9, 1991 (DOE-ID 1991). Under terms of the FFA/CO, the entire RWMC is being evaluated under the Waste Area Group (WAG) 7 comprehensive remedial investigation/feasibility study (RI/FS), OU 7-13/14.

The OU 7-08 ROD (DOE-ID 1994) was issued as final on December 2, 1994. According to the ROD, the selected remedy consists of the extraction and destruction of organic contaminant vapors present in the vadose zone beneath and within the immediate vicinity of the RWMC, and the monitoring of vadose zone vapors and the SRPA in the vicinity of the RWMC.

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b. Transuranic waste is radioactive waste containing more than 100 nCi of alpha-emitting transuranic isotopes per gram of waste, with a half-life greater than 20 years.

To implement the selected remedy described in the OU 7-08 ROD, five new vapor extraction wells (1E through 5E) and 10 new vapor monitoring wells (1V through 10V) were installed in or adjacent to the SDA during 1994. In addition to the new extraction and monitoring wells, one extraction (8901D) and five monitoring wells (8801, 8902, DO2, 9301, and 9302) previously installed for an OCVZ treatability study conducted in 1993 (Duncan, Troutman, and Sondrup 1993) were incorporated for extracting and monitoring VOCs.

To meet the OU 7-08 ROD objectives, three VVET units were designed, built, and installed within the boundaries of the SDA. Two of these units (designated as VVET Units A and B) relying on recuperative flameless thermal oxidation treatment were designed to extract and treat vapors from two extraction wells each. Another recuperative flameless thermal oxidation treatment unit (designated as VVET Unit C) was designed to extract and treat vapors from one extraction well. On January 11, 1996, remediation of VOCs from the subsurface of the RWMC commenced.

The original VVET system operated without any significant changes until the fall of 1999. Since that time, several new combination vapor/groundwater monitoring wells and combination vapor monitoring/extraction wells have been drilled. In addition, the three original recuperative flameless thermal (propane) oxidizers (VVET Units A, B, and C) have each been replaced with electrically heated catalytic oxidizers designated VVET Units D, E, and F. Replacement of the propane oxidizers was due to frequent breakdowns and high maintenance costs. The new catalytic oxidizers were manufactured by King Buck Technology of San Diego[c] and are designed to extract from multiple wells. Table 1-2 shows the significant modifications and additions made to the original VVET operation and monitoring system since operations began.

Table 1-2. Significant modifications to the VVET operations and monitoring system.

Date	Modification	Comment
1999/2000	Constructed wells DE1, M15S, M16S, and M17S	Wells DE1 and M17S are located inside the SDA and monitor volatile organic compound (VOC) vapor concentrations in the deep vadose zone (below C-D interbed) and VOCs in groundwater. DE1 also has an extraction zone below the C-D interbed. M15S and M16S are located east of the Radioactive Waste Management Complex (RWMC) and monitor the vadose zone and groundwater.
Spring 2000	Constructed wells 6E and 7E	These are shallow vapor extraction wells located near Pits 4 and Pad A respectively. The extraction interval is above the B-C interbed and is open borehole. This is different than previous extraction wells (except 8901D) that use slotted PVC pipe with a surrounding sand pack for the extraction zone.
July 2001	Unit D replaced Unit C and starts operation. Full-scale operation began March 2002	Unit C failed May 31, 2000, and the unit was decommissioned and removed Spring 2001. Unit D placed in the same location as Unit C. Unit D is connected to well 7V initially, but is later connected to four wells (7V, SE6, IE6 and DE6).

c. References herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the U.S. Government, any agency thereof, or any company affiliated with the Idaho Cleanup Project.

Table 1-2. (continued).

Date	Modification	Comment
2002/2003	Constructed 14 new wells (SE3, IE3, DE3, IE4, DE4, SE6, IE6, DE6, SE7, IE7, DE7, SE8, IE8, DE8)	The SE wells are vapor extraction wells, and the IE and DE wells are combination vapor monitoring/extraction wells. The S, I, and D prefix designates the depth of the extraction zone with S being Shallow (above B-C interbed), I being Intermediate (between the B-C and C-D interbeds) and D being Deep (below C-D interbed). The extraction zones are open borehole. The locations of the IE and DE wells are shown in Figures 7-2 and 7-3. SE wells, while not shown in the figures, are located next to the IE and DE wells of the same number.
January 2004	Unit F replaces Unit B and starts operation. Full-scale operation began March 2004	Unit B ceased operation February 12, 2003, and the unit was decommissioned and removed shortly thereafter. Unit F was not placed in the same location as Unit B; rather it was placed close to well 2E. Unit F is connected to ten wells (SE3, IE3, DE3, 7E, IE4, DE4, SE8, IE8, DE8 and 2E)
March 2004	Unit E replaces Unit A and starts operation. Full-scale operation began April 2004	Unit A ceased operation September 25, 2003, and the unit was decommissioned and removed shortly thereafter. Unit E was originally placed in the same location as Unit A and connected to six wells (6E, DE1, 8901D, SE7, IE7 and DE7). Unit E was relocated in March 2005.
November 2004	Unit E extraction from DE1 and 6E discontinued to re-route the wells beneath the north foundation of the Accelerated Retrieval Project (ARP) Phase II enclosure.	Unit E and associated piping and electrical subsystems planned for relocation to the south of Pit 4 to allow ARP II extension east on Pit 4.
March 2005	Unit E relocation activities begin	Unit E temporarily shut down to relocate the treatment system and associated piping and electrical systems to the south of Pit 4 allowing ARP II extension east on Pit 4. Vapor monitoring temporarily discontinued for wells IE7, DE7, and 9301. Vapor monitoring discontinued for wells 8801 and 9302 until after decontamination and decommissioning of ARP II enclosure.
May 2005	Unit E relocation activities complete. Full scale operation of Unit E planned.	Unit E restarted following move to new location south of Pit 4. Piping to wells SE7, IE7, DE7, and 8901D routed beneath the south foundation of ARP II enclosure. Vapor monitoring resumed for wells IE7, DE7, and 9301.

As provided in the *Environmental and Operational End-Year Data Report for the OU 7-08 Organic Contamination in the Vadose Zone Project - 2004* (Housley 2005), as of December 31, 2004, a total of 87,100 kg (192,000 lb) of VOCs have been treated since the beginning of the remedial action. This total comprises chloroform (13,200 kg [29,000 lb]), 1,1,1-trichloroethane (TCA) (4,500 kg [9,900 lb]), tetrachloroethene (PCE) (3,200 kg [7,000 lb]), trichloroethene (TCE) (13,200 kg [29,000 lb]), and carbon tetrachloride (53,000 kg [117,000 lb]). As can be derived from the data, carbon tetrachloride accounts for 61% of the VOCs treated. Figure 1-3 provides a graph of the analyte mass contribution to the total VOCs removed and treated. Figures 1-4 and 1-5 represent horizontal cross sections of the carbon tetrachloride concentration distribution at the 21-m (70-ft) level for two specific times: (1) before commencing the remedial action on January 4, 1996, and (2) in May 2005. These figures indicate that the areal extent of the VOC plume has decreased since VVET operations began and that carbon tetrachloride concentrations at the center of the plume also have decreased. However, Figure 1-5 can be misleading in that it does not take into account rebound effects. In other words, the concentrations and resulting distribution maps are highly sensitive to the operations of the VVET system. When the units are operating, the concentrations in surrounding wells are reduced. When the units are shut down, there is a rise, or rebound, in the concentrations. All three VVET units were operating during April 2005. Therefore, the concentrations depicted in Figure 1-5 are presumed to be lower than if the VVET units had not been operating.

1.6.3 Volatile Organic Compound Inventory

The first estimate of VOCs buried in the SDA was done by Kudera (1987). Since that time, the inventory estimate of CCl_4 and other VOCs has been updated and refined as new information was discovered or became available. Table 1-3 lists the sources of published historical CCl_4 estimates. The evolution of the estimates is depicted graphically in Figure 1-6.

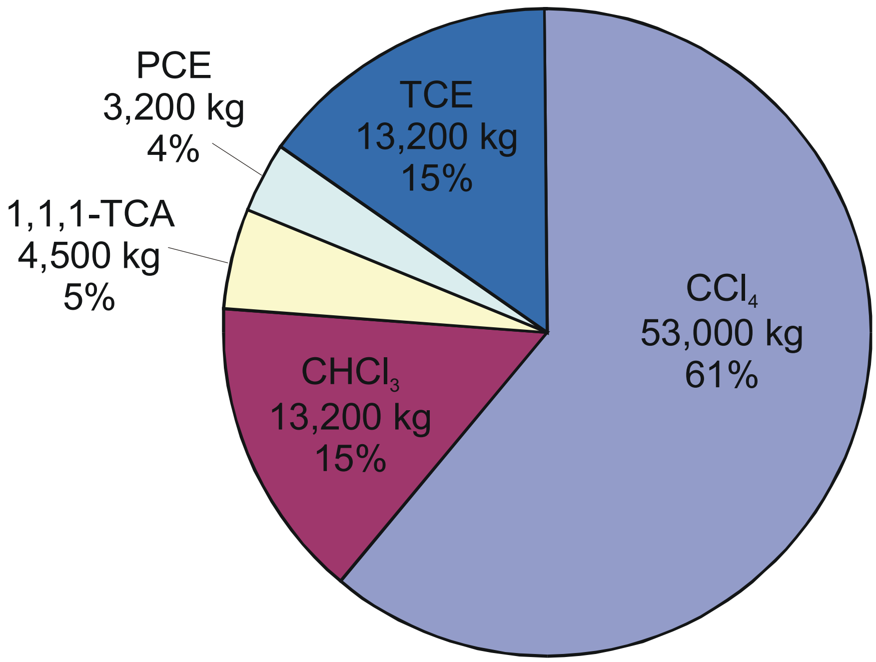

Figure 1-3. Ratio of analyte mass contribution to total volatile organic compound mass removed by the VVET system from January 1996 through December 2004.

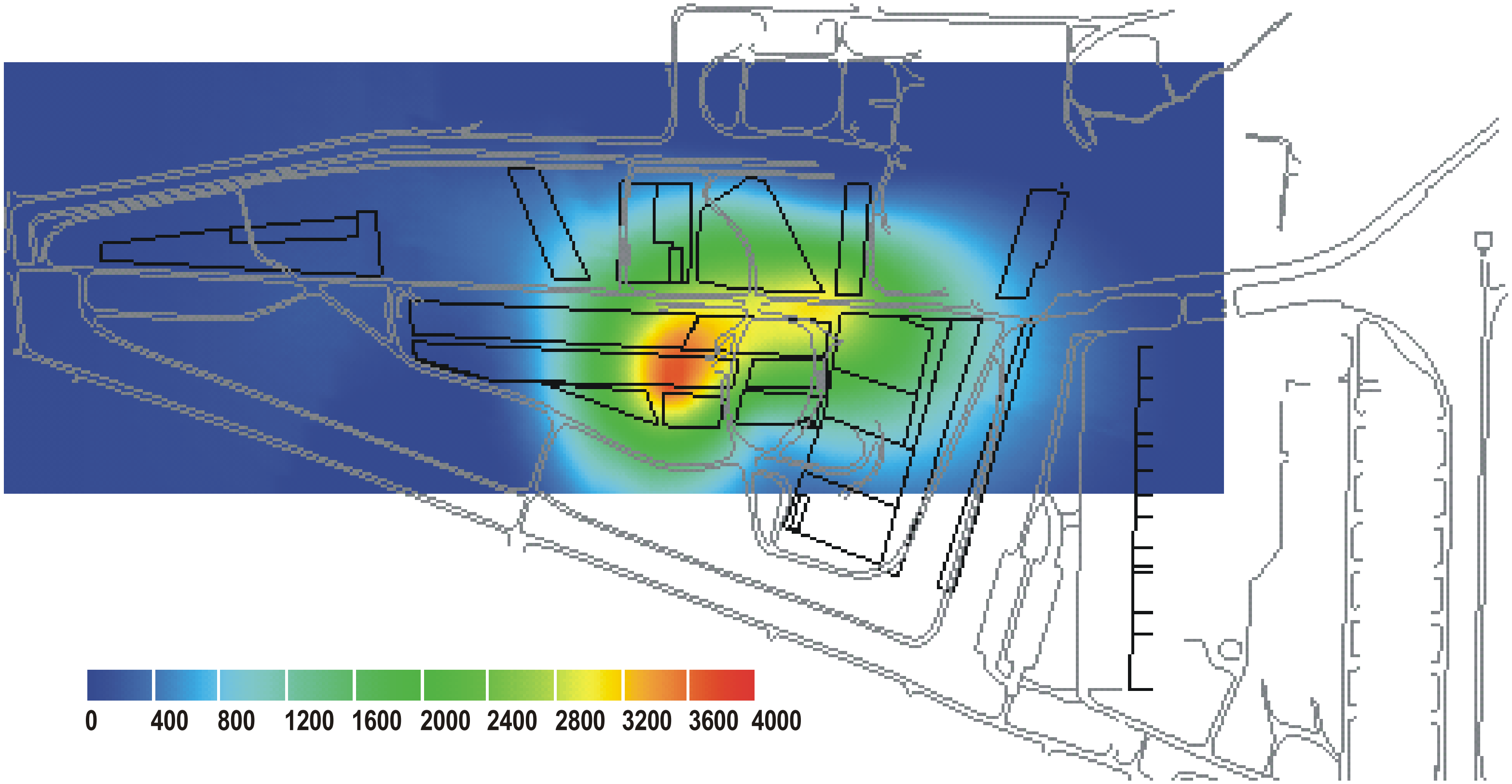

Figure 1-4. Spatial distribution of carbon tetrachloride vapor at approximately 21 m (70 ft) below ground surface for January 4, 1996.

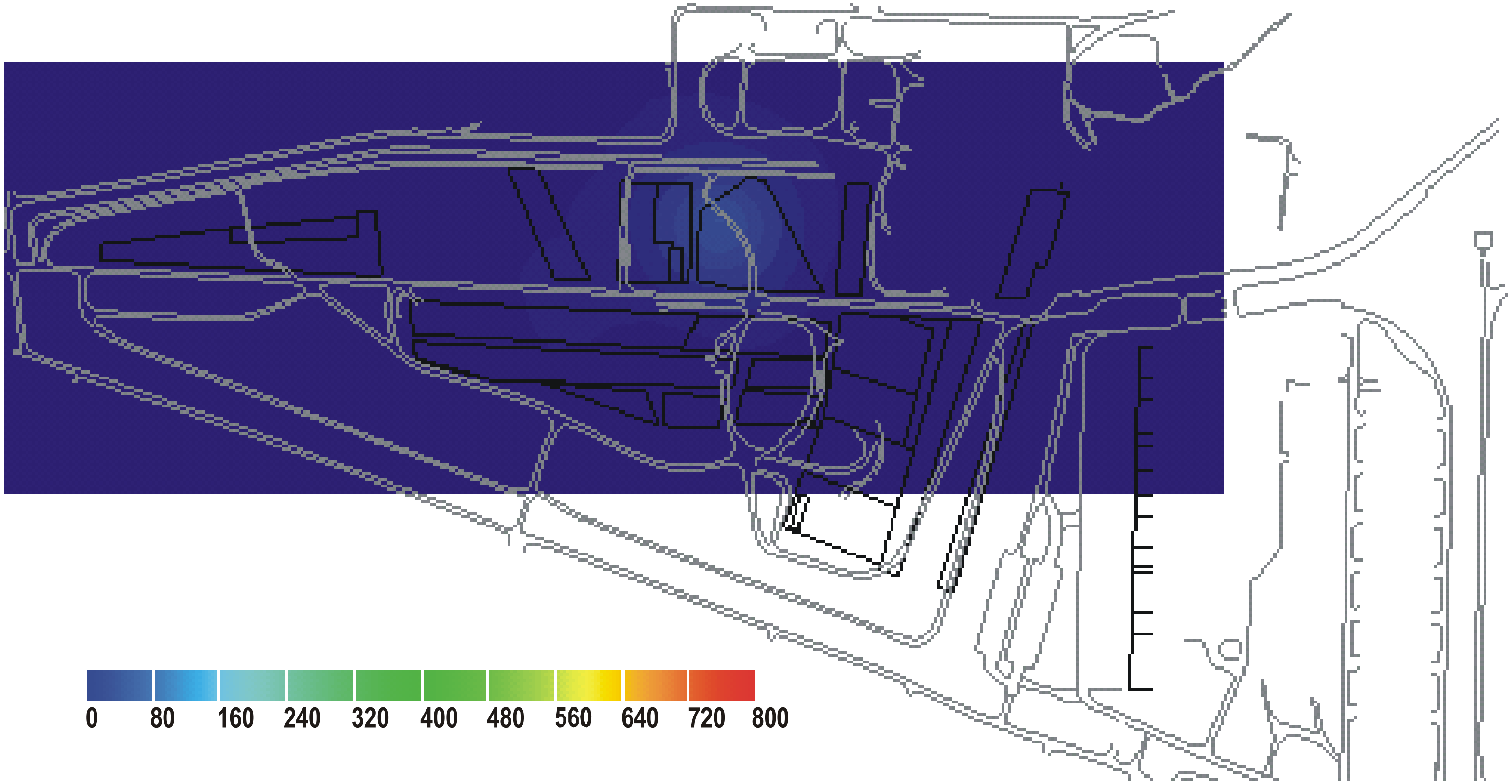

Figure 1-5. Spatial distribution of carbon tetrachloride vapor at approximately 21 m (70 ft) below ground surface for May 2005.

Table 1-3. History of carbon tetrachloride inventory estimate.

Source	Mass Estimate (kg)	Description
Kudera (1987)	1.5E+05	This inventory estimate was incorporated in the OCVZ RI/FS (Duncan, Troutman, and Sondrup 1993).
Historical Data Task (LMITCO 1995)	1.13E+05	The inventory in the Historical Data Task reduced the estimate in Kudera (1987) by 25% to account for losses of the volatile components during waste processing and storage. This was the best estimate. The Kudera estimate was listed in the Historical Data Task as the upper bound.
Interim Risk Assessment (Becker et al. 1998)	2.26E+05	The Historical Data Task (LMITCO 1995) best estimate inventory was arbitrarily doubled in order to calibrate the Interim Risk Assessment fate and transport model.
Miller and Navratil (1998)	4.9E+05 kg	Monthly rather than yearly shipping records were reviewed, and inconsistencies in the records were identified. Assumptions were made to resolve inconsistencies with Kudera (1987).
Miller and Varvel (2001)	8.2E+05 kg	New sources of information were used that became available following inquiries made during the Miller and Navratil (1998) investigation.
Miller and Varvel (2005)	7.9E+05 kg	The original mass amount in Miller and Varvel (2001) was revised slightly by preserving a more appropriate number of significant digits in the recalculations

OCVZ = organic contamination in the vadose zone
RI/FS = remedial investigation/feasibility study

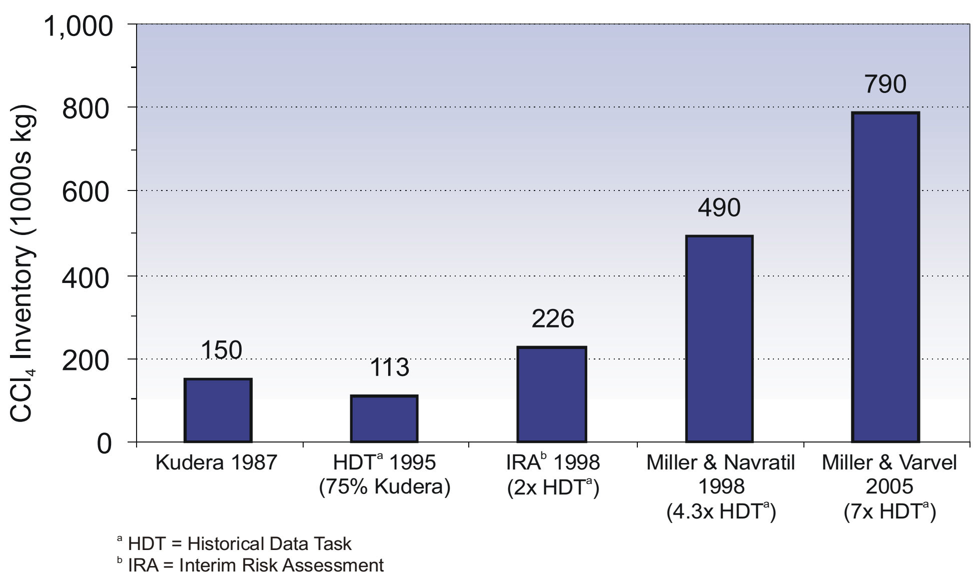

Figure 1-6. Evolution of historical carbon tetrachloride inventory estimates.

The most recent estimate of CCl_4 buried in the SDA (Miller and Varvel 2005) is a result of the most comprehensive investigation and is believed to be the most accurate. This estimate of 7.9E+05 kg is greater by a factor of seven than the best estimate reported in the Historical Data Task (HDT) Report, *A Comprehensive Inventory of Radiological and Nonradiological Contaminants in Waste Buried in the Subsurface Disposal Area of the INEL RWMC During the Years 1984–2003* (LMITCO 1995).

Varvel (2005) estimated the amount of non-CCl_4 VOCs in the 743-series waste by assuming that the non-CCl_4 fraction reported by Miller and Varvel (2005) was made up of equal volumes of PCE, TCE, and TCA. Based on this assumption, Varvel estimated that the original PCE inventory was 9.9E+04 kg, which is 360% of the best-estimate value reported in the HDT report (LMITCO 1995). The TCE inventory estimate was 8.9E+04 kg (or 89% of HDT value) and the TCA inventory estimate was 8.2E+04 kg (or 74% of HDT value).

1.6.4 Extent of Contamination

The nature and extent of contamination associated with the SDA in all environmental media were evaluated for the *Ancillary Basis for Risk Analysis for the Subsurface Disposal Area* (Holdren et al. 2002). The Ancillary Basis for Risk Analysis (ABRA) provided an initial list of human health contaminants of potential concern (COPCs) containing 12 radionuclides and four chemical contaminants. Four radionuclides and three chemical contaminants also were included as ecological COPCs in the ABRA.

In addition to routine monitoring at the RWMC, several unique approaches were adopted to characterize the nature and extent of contamination for the ABRA. To describe the waste zone, a database containing the contaminant inventories and waste descriptions was developed. The inventory information was captured in the Contaminant Inventory Database for Risk Assessment (CIDRA). A second database was created to map characterization data and disposal locations in the SDA. Called WasteOScope, the mapping software is based on historical disposal records including shipping manifests and trailer load lists. The two separate databases are being combined into one application—the Waste Inventory Location Database (WILD). This application includes the modifications to the inventory developed since the CIDRA database was developed. In addition, it contains all disposal mapping information originally in the WasteOScope. By combining the two separate databases, WILD facilitates assigning inventory to disposal areas so that areas of higher contaminant concentration can be targeted for remediation. In addition, electromagnetic and soil gas surveys were evaluated against waste zone maps. More than 300 probes were installed to characterize the buried waste using instruments developed at the INL. The data from the surveys and the probes were incorporated into WILD to allow visual superposition of various data sets.[d]

The evaluation of the nature and extent of contamination concluded that low concentrations of carbon tetrachloride, nitrates, and C-14 were affecting the aquifer near the SDA. Groundwater monitoring data for the past two years no longer support the claim that nitrates and C-14 are impacting the aquifer. Carbon tetrachloride has been identified slightly above the maximum contaminant level (MCL) in roughly one-third of the wells monitored. Otherwise, the contaminants buried in the SDA have not impacted groundwater quality, though several contaminants have been detected at low concentrations in the vadose zone and may be migrating. Most vadose zone detections or radionuclides and inorganic contaminants are in the 0- to 10.6-m (35-ft) and 10.6- to 42.6-m (35- to 140-ft) intervals above the B-C interbed. Some contaminants have been detected in the deeper intervals. In general, the most frequently detected contaminants in the environment include nitrates, C-14, Tc-99, and uranium isotopes. Other contaminants, including Am-241, I-129, Nb-94, Np-237, Pu-239, Pu-240, and Sr-90, have been detected sporadically at concentrations near the detection limits (Holdren et al. 2002).

Volatile organic compounds from the SDA have formed a large vapor plume in the vadose zone around the RWMC that extends to the aquifer. The primary contaminants are carbon tetrachloride, chloroform, and trichloroethene, with carbon tetrachloride being the most prevalent. The contamination

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d. McKenzie, M. D., D. E. Sebo, K. M. Green, V. G. Schultz, 2005, "Waste Information and Location Database Update for the OU 7-13/14 Project (Draft)," ICP/EXT-04-00271, Idaho Completion Project, May 2005.

extends vertically from land surface down to the water table and laterally greater than 1 km from the SDA boundary. The highest concentrations (3,000 to 5,000 ppmv) outside the waste zone have been measured between Pits 4, 6, and 10 in the center of the SDA above the 33.5-m (110-ft) B-C interbed. In this region, concentrations increase with depth, down to the 33.5-m (110-ft) B-C interbed, and then decrease down to the 73-m (240-ft) C-D interbed. The maximum lateral extent of contamination is undefined, but the concentrations diminish with distance from the SDA (see footnote d).

Monitoring data collected subsequent to the ABRA report is published in annual reports. The most recent of these is *Fiscal Year 2004 Environmental Monitoring Report for the Radioactive Waste Management Complex* (Koeppen et al. 2005). These reports document the extent of contamination for the COPCs specified in the ABRA as well as other contaminants of interest.

1.6.4.1 Estimate of Residual Source Mass in the Subsurface Disposal Area Pits and Trenches. The OCVZ project considers the residual VOC source mass a critical element in making predictions of future risk and required cleanup times. When Revision 1 of the original DQO Summary Report was issued in 2002, no estimate had been determined for the amount of VOCs remaining in the pits. In lieu of an estimate of residual VOC mass, the project proposed to track traits and trends in residual VOC release through transient observations of shallow soil gas and soil gas flux. Shallow soil gas measurements were to be taken over three primary areas known to contain the largest amounts of VOCs: (1) the west end of Pit 10; (2) the east end of Pit 4, near the northern junction with Pit 6; and (3) the southern end of Pit 9. Shipping and disposal records indicate nearly all of the VOC sludge was buried in these locations (Miller and Varvel 2001). The results of a previous soil gas survey that confirms the process knowledge data and hot spot areas (i.e., areas with high levels of contamination) are represented graphically in the shallow soil gas survey map in Figure 1-7.

Additional shallow soil gas surveys could not be performed due to conflicts with other higher priority projects that precluded access to the areas. The primary projects were: (1) the Glovebox Excavator Method Project, which removed buried waste from Pit 9; (2) the OU 7-13/14 probing project, which installed hundreds of shallow instrumented and uninstrumented probeholes in the SDA surficial sediments; and (3) Phase I of the ARP, which will remove buried waste from the eastern end of Pit 4.

Recently, a study was conducted that attempted to use data from some of the probes installed in the SDA to provide a preliminary estimate of the mass of CCl4 remaining in the SDA pits (Sondrup et al. 2004). The estimate is based on calculations of CCl4 originally buried in the SDA (Miller and Varvel 2001) and the results of recent chlorine logging in the waste. The chlorine logging was performed in probe holes laid out in a transect through 743-series waste in Pit 4. The chlorine logging provides the basis for estimating the current mass of CCl4 and total VOCs at select locations within the SDA. The study attempted to quantify and propagate random errors in both data sets to provide an estimate of the uncertainty in the final VOC mass estimate.

The attempts to quantify VOC mass remaining in SDA pits were largely unsuccessful based on the lack of quantifiable uncertainty around the original chlorine mass per probe-hole estimate and the inadequacy of the neutron-gamma logging tool calibration function. A revised strategy that also relied on neutron-gamma logging data was also unsuccessful because of (1) the inability to distinguish Series 743 sludge from other media (e.g., soil and debris) and (2) the inability to develop a tool response function capable of predicting all observed neutron-gamma data.

Year 2000 Shallow Soil Gas Survey CCl_4 Results - Pits 4, 5, 6 and 10

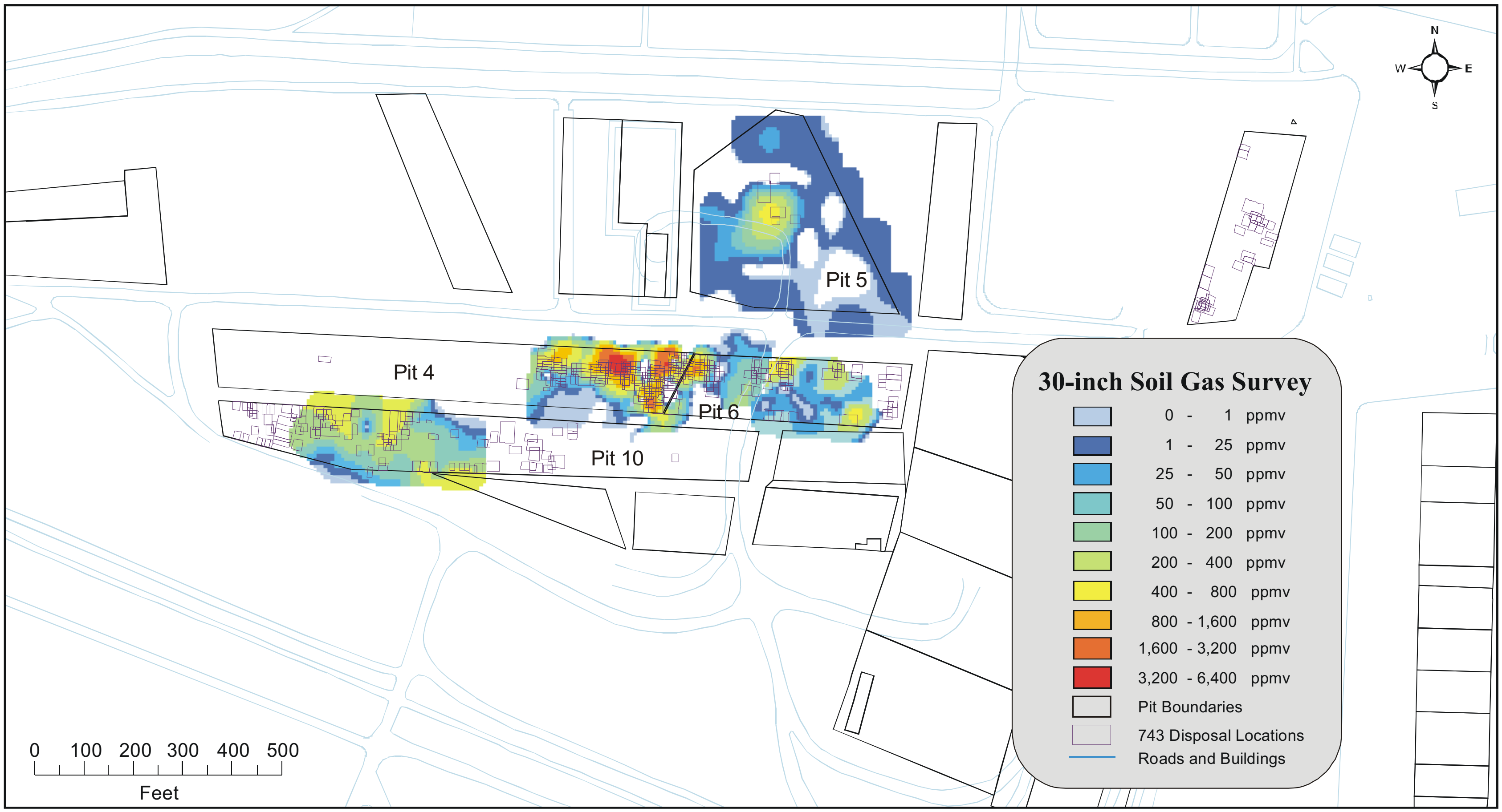


Figure 1-7. Plan view of Subsurface Disposal Area showing volatile organic compound hot spot locations.

An alternative, simpler approach was used to approximate the amount of VOC mass remaining without any attempt to quantify the uncertainty. Based on this approach, an estimate of 50% VOC mass remaining was recommended as a starting point for numerical modeling to predict risks and remediation goals for OU 7-08 and OU 7-13/14. An estimate of 75% mass remaining was recommended as an upper bound. However, users of this information were cautioned that the lack of uncertainty surrounding these estimates should be carefully considered in interpreting any results derived from their use.

Regardless of the uncertainty, the mass of VOCs estimated to remain in the pits is relatively large, and depending on the release rate, the source could be active for many years.

1.6.5 Accelerated Retrieval Project

In 2004, the DOE began a non-time Critical Removal Action (NTCRA) to perform a targeted retrieval of certain Rocky Flats Plant waste streams at the SDA that are highly contaminated with TRU radionuclides, VOCs, and various isotopes of uranium. The ARP is tasked with performing the waste retrieval work in the SDA. Waste removal objectives for the ARP are defined in the *Engineering Evaluation/Cost Analysis for the Accelerated Retrieval of a Designated Portion of Pit 4* (DOE-ID 2004).

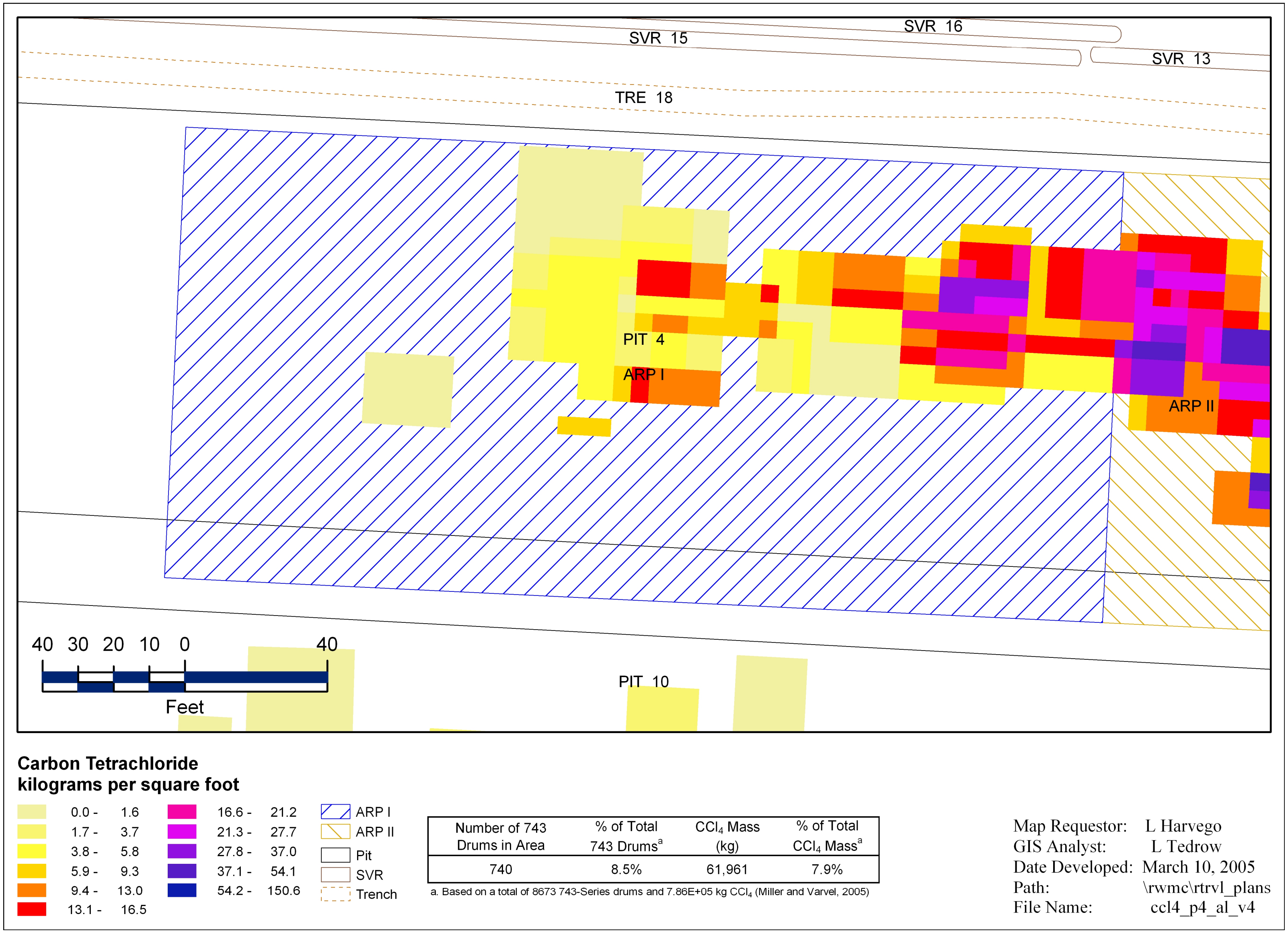
The ARP will be executed in several phases to achieve the objective of SDA targeted waste retrieval. Phase I (ARP I) began retrieving waste in December 2004 from a described area of Pit 4 shown in Figure 1-8. Based on disposal records, approximately 8% of the total CCl_4 inventory is located in the ARP I area. The planned retrieval operational period for ARP I is scheduled for 12 months, followed by a 6-month deactivation, decontamination, and decommissioning phase. Performance of Waste Isolation Pilot Plant (WIPP)-related processing and certification activities will be a fundamental element of proposed NTCRA activities and is expected to require several years to complete, but a final schedule is not available at this time.

The ARP Phase II (ARP II) retrieval enclosure, currently under construction, will expand from the ARP I retrieval area to the east, encompassing portions of Pits 4 and 6 (Figure 1-9). The selection of the areas within Pits 4 and 6 as the retrieval area was based on evaluation of the shipping and burial records of containerized radioactive materials and sludge from the Rocky Flats Plant and low-level waste generated at INL. While the area within the ARP II enclosure contains 46.0% of the total CCl_4 inventory based on disposal records, it has not yet been determined if all or a portion of the ARP II area will be excavated.

The combined total CCl_4 inventory in ARP I and II is more than one-half of the total SDA inventory. Although much of the original VOC waste has been released and transported away from the pits primarily by vapor diffusion and advection (Magnuson and Sondrup 1998), Sondrup et al. (2004) estimate a substantial portion of the inventory remains. One of the global issues identified by this DQO (Section 1.4.1) was that the selected remedy does not include treatment of the buried waste, and the remaining VOCs could extend the timeframe required to achieve RAOs. The success of ARP will have a significant impact on the amount of VOC waste that remains and the time required for achieving RAOs.

1.6.6 Vapor Vacuum Extraction with Treatment System Shutdown Requirements

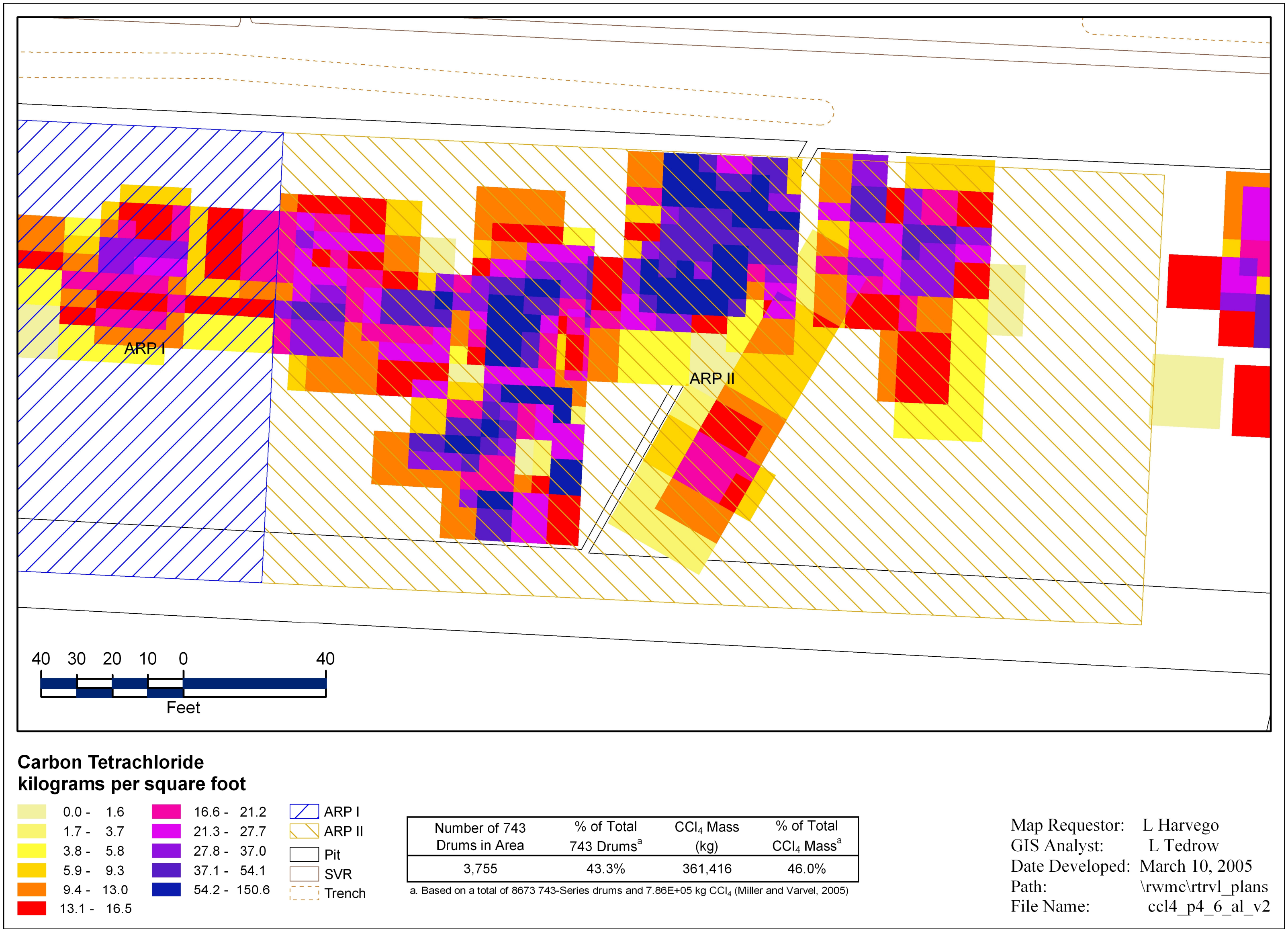
As stated in Section 1.6.2, remediation of VOCs from the subsurface of the RWMC by VVET commenced on January 11, 1996. At this writing, the VVET system consists of three VVET units (D, E, and F) and 18 extraction wells (2E, SE8, IE8, DE8, SE3, IE3, DE3, 7E, IE4, DE4, 7V, SE6, IE6, DE6, SE7, IE7, DE7, and 8901D). Monitoring indicates that the organic vapor plume concentrations have decreased within the area of the VVET system influence (Housley 2005).



Number of 743 Drums in Area	% of Total 743 Drums[a]	CCl_4 Mass (kg)	% of Total CCl_4 Mass[a]
740	8.5%	61,961	7.9%

a. Based on a total of 8673 743-Series drums and 7.86E+05 kg CCl_4 (Miller and Varvel, 2005)

Figure 1-8. Accelerated Retrieval Project I location in the east end of Pit 4 shown with 743-series waste drum burials.



Number of 743 Drums in Area	% of Total 743 Drums[a]	CCl_4 Mass (kg)	% of Total CCl_4 Mass[a]
3,755	43.3%	361,416	46.0%

a. Based on a total of 8673 743-Series drums and 7.86E+05 kg CCl_4 (Miller and Varvel, 2005)

Figure 1-9. Accelerated Retrieval Project II location in Pits 4 and 6 shown with 743-series waste drum burials.

The primary thrust of this DQO is the development of a sampling design that enables the RAOs promulgated in the ROD (DOE-ID 1994) to be satisfied. This is a unique challenge because the VVET system is expected to meet the RAOs well before the 100-year institutional control period ends. Therefore, a predictive component must be factored into the decision to shut down the VVET system that is independent of measured groundwater concentrations.

The OCVZ project will base the VVET system shutdown decisions on predictive fate and transport modeling. The model relies on vadose zone vapor concentration measurements to predict the resulting groundwater organic contaminant concentrations after the 100-year institutional period. The PORFLOW model was used initially to develop PRGs, which were subsequently published in the ROD. This model has since been replaced with a more appropriate model, TETRAD (Vinsome and Shook 1993). The TETRAD model is considered more appropriate because it is a true multiphase model and is able to simulate more of the physical processes thought to be important in the transport of VOCs. The PORFLOW model was only a single-phase model, though efforts to include the impacts of an additional phase were included in the original PORFLOW modeling. In the past, engineering efforts on the TETRAD models focused on refining the model vapor plume predictions, not PRG development.

The TETRAD model has recently been used to establish vapor concentration PRGs for the vadose zone beneath the SDA. Vapor concentration data and vapor plume trends predicted by the TETRAD model indicate that three vertical strata, or zones, exist beneath the SDA, with differing potential to contaminate the underlying SRPA. Each of the three vertical zones, depicted in Figure 1-10, will be assigned a unique PRG value based on its potential to contaminate groundwater. Each of these PRG zones plays a role in the VVET shutdown decision-making and is discussed further in the DQO steps detailed in Sections 2 through 7.

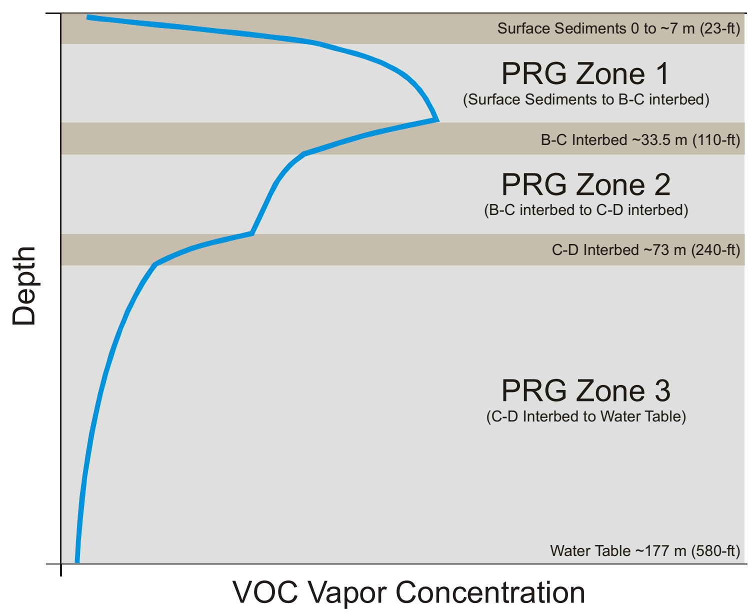


Figure 1-10. Preliminary remediation goal zones relative to depth. Generic VOC vapor concentration profile shown is indicative of the conditions and relative magnitudes in the center of the SDA.

In addition to dividing the vadose zone into separate vertical zones for the purpose of establishing PRGs, two different areal or horizontal regions, A and B, were defined. Region A is defined as the portion of the plume within the influence of the current VVET system, and Region B is the portion outside the influence of the system. The significance of these regional distinctions to the decision-making process is described in more detail in Section 4.

The PRGs developed from the TETRAD model could be revised as the model is refined, but significant change to the PRGs is not anticipated. Once the Agencies have formally accepted the PRGs, they will become remediation goals (RGs). At this time, decision-makers and OCVZ project personnel agree that the model has matured enough to provide long-term predictions of vapor plume behavior and consequential groundwater contamination levels.

In addition, fulfilling the RAOs will not be based solely on meeting the PRGs. Other requirements must be met to support the VVET shutdown decision:

- Statistical requirements (discussed in Section 5, DQO Step 5).
- The fate and transport model will be run in a forward fashion using the measured vapor concentrations as a base condition to predict organic contaminant concentrations in groundwater after the 100-year institutional period.
- Model results must be satisfied during a compliance verification period after VVET system shutdown. The verification period is required because vadose zone plume behavior must be favorable under quiescent conditions as well as during the dynamic pressure conditions that exist during vapor extraction.

1.6.6.1 Monitoring Periods. Monitoring strategy will focus on three primary periods: (1) the VVET system operation period; (2) the quiescent period following VVET operations (also known as the compliance verification period); and (3) the long-term monitoring period.

Vapor monitoring must be performed during VVET system operations to track system performance against PRGs. The VVET system operation induces artificial dynamic low-pressure conditions that may cause vapor concentrations to rebound somewhat after the system is shut down. Therefore, to verify that vapor concentrations remain within acceptable limits under natural pressure conditions in the vadose zone, monitoring must be performed during the quiescent compliance verification period. If vapor concentrations and trends meet certain criteria, the OCVZ project will enter into the long-term monitoring phase, during which sampling frequencies will be reduced and the VVET systems will be mothballed, provided VVET restart is not imminent. If vapor concentrations and trends do not meet the criterion (i.e., unacceptable rebound concentration), the VVET system will be restarted.

The OCVZ project plans to shut down the VVET system operations on a periodic basis for short-term rebound. These short-term rebound periods will be scheduled with Agency concurrence. Vadose zone rebound concentrations will be monitored during these scheduled shutdown periods. These short-term rebound periods are distinct from the compliance verification phase. Compliance verification will be initiated only after the monitored vapor concentrations satisfy the conditions required by the shutdown decisions.

The relationship between the VVET operating, compliance verification, and long-term monitoring periods is shown in the logic flow diagram provided in Figure 1-11.

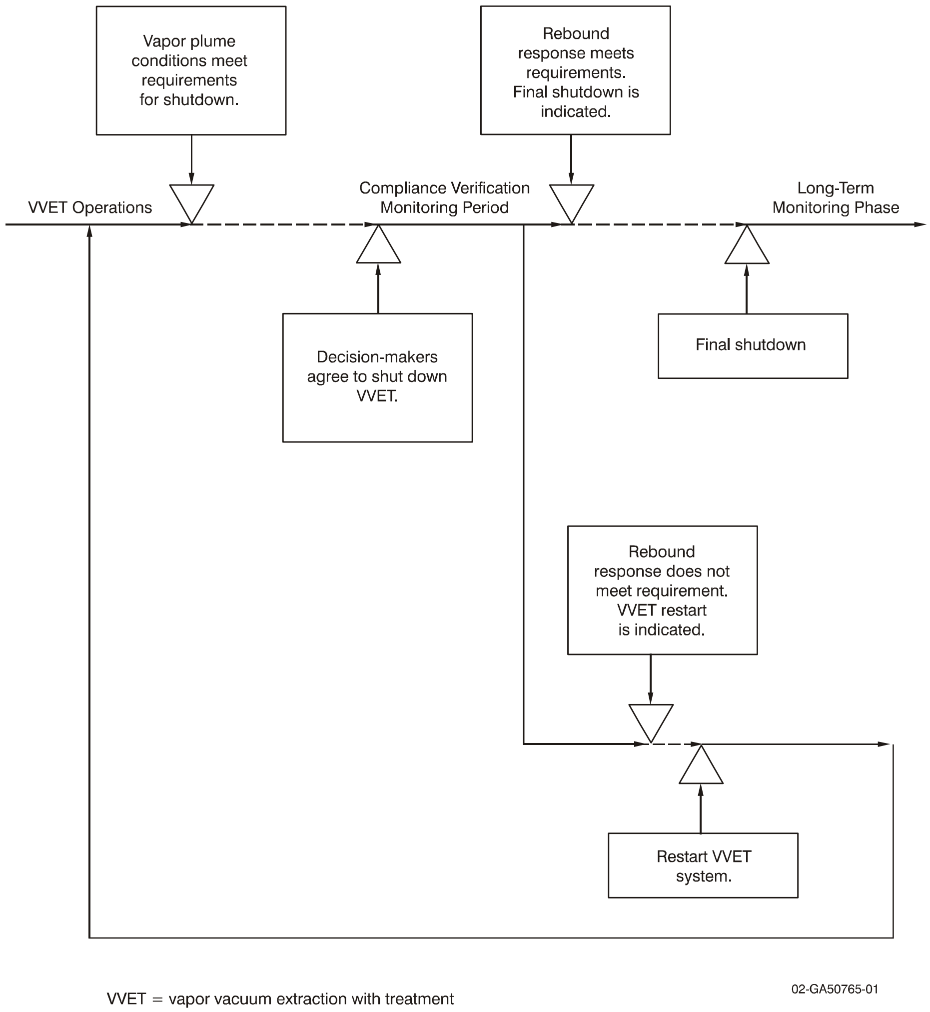


Figure 1-11. Vapor vacuum extraction with treatment operating and compliance verification period relationship logic flow diagram.

1.6.6.2 Groundwater Monitoring. As discussed in Section 1.6.6, organic chemical concentrations in groundwater cannot serve as a direct indication that the VVET systems may be shut down because groundwater monitoring has no *per se* predictive function. However, as long as groundwater monitoring is performed under DOE operations, the analytical results will be used to confirm the groundwater contaminant concentrations predicted by the fate and transport model.

1.6.7 Preliminary Remediation Goal Use

As noted in Section 1.6.6, the RGs developed using the model are for comparison with measured vapor concentrations, and the measured vapor concentrations will be incorporated into the fate and transport model for final analysis. This dualistic approach is based on specific requirements. The RAOs and PRGs were specified in the OU 7-08 ROD and are essential to the VVET shutdown decision for the following reasons:

- The RGs will be compared with the measured vadose zone vapor concentrations and changes over time, thereby providing a metric for OCVZ project personnel and decision-makers to evaluate VVET system performance

- Measured vapor concentrations will be evaluated against RGs through the statistical tests to verify fulfillment of the RAOs (upper confidence level [UCL] and trend analyses).

1.6.8 Point of Compliance

The point of compliance is the point or points where the cleanup levels are established. From a regulatory standpoint, the point of compliance for the OCVZ project is the SRPA outside the SDA boundary. The point of compliance is outside the fence because land use at the RWMC will be limited to industrial applications with active institutional controls until the year 2110. For the next 900 years beyond that, the land use is assumed to be nonresidential with passive controls (Holdren and Broomfield 2004) (also see Section 1.9). Compliance would ensure that the VVET shutdown decision is protective of all areas that could be influenced by the remaining VOC contamination within the vadose zone. The potential exists, however, for other environmental conditions, such as those listed below, to affect groundwater through mechanisms that are beyond the ability of the OCVZ system to control:

- Spreading area waters—During high run-off periods, excess water from the Big Lost River is diverted to low-lying playas, or spreading areas, southwest of the RWMC. Results of past tracer tests indicate that water from the spreading areas travels through the vadose zone under the RWMC (Nimmo et al. 2002). This water is hypothesized to "scrub" some of the organic contaminants from the RWMC vadose environment, thereby becoming contaminated. As the water continues through the vadose zone, it migrates away from the SDA through preferential pathways and eventually to groundwater. Groundwater monitoring performed in wells to the north and east of the SDA has shown elevated levels of VOCs, which support this hypothesis.

- Potential flooding events within the SDA—Because the SDA resides in a basin, significant flooding events could occur within the SDA, as occurred during past years such as 1962, 1969, and 1982. The flood waters could release moisture fronts directly into VOC-contaminated sedimentary soil, the vadose zone, and ultimately groundwater.

The OCVZ DQO is focused on a shutdown decision for VVET systems that effectively have reduced the mass of organic vapors within the vadose zone. These systems cannot, however, control impacts to groundwater caused by spreading area waters or flooding. Therefore, the scope of this DQO will be limited to the conditions that the OCVZ system can control. This is discussed in DQO Step 4 where the spatial scale of decision-making is established.

1.7 Data Quality Objective Team Members and Key Decision-Makers

During the original formulation of the DQO, individual members of the DQO team were selected carefully to participate in the seven-step DQO process based on their technical background to provide expertise in all of the technical areas needed to meet the task objectives. The key decision-makers included representatives from DOE, DEQ, and EPA Region 10. The role of the key decision-makers was, and continues to be, to make final decisions related to the sampling design.

1.8 Contaminants

A list of the contaminants of concern (COCs) normally is developed through the DQO process. A list of all COPCs is developed based on historical process operations and existing data. Certain COPCs subsequently are excluded from consideration based on practical and physical factors such as short half-life, absence of risk, or process knowledge. A final COC list is established through this process and its development is documented.

The OCVZ COC list was developed through a baseline risk assessment (Duncan, Troutman, and Sondrup 1993) that screened the potential contaminants and selected a final list based on risk. Therefore, the COC list from the baseline risk assessment applies without modification to the fulfillment of the OCVZ DQO. The final list of COCs that will be evaluated through the DQO process is presented in Table 1-4.

Table 1-4. Final list of contaminants of concern.

Medium	Contaminants of Concern[a]
Contaminated vadose zone (fractured basalt)	Carbon tetrachloride[b], 1,1,1-trichloroethane, trichloroethene, and tetrachloroethene

a. Chloroform is present in the vadose zone primarily as a degradation product of carbon tetrachloride, but was not identified as a contaminant of concern (COC) in the project baseline risk assessment. Likewise, it is not shown as a COC here. However, sample analyses will include chloroform for tracking purposes.

b. Carbon tetrachloride will be used as an indicator for the three other COCs; however, the other contaminants will be modeled as well.

A description of how each of the COCs arrived at the site is identified in Table 1-5, along with the fate and transport mechanisms (e.g., wind or water) that may have impacted the distribution (e.g., layering or lateral homogeneity) of each COC.

Table 1-5. Distribution of contaminants of concern.

Medium	Contaminants of Concern	Arrival Mechanism	Fate and Transport Mechanism	Expected Distribution
Vadose zone (fractured basalt)	Carbon tetrachloride, 1,1,1-trichloroethane, trichloroethene, and tetrachloroethene	Rocky Flats solidified oil waste in 55-gal drums buried in the Subsurface Disposal Area	Leakage from drums and migration of volatile organic compounds in the vadose zone under the Subsurface Disposal Area	Heterogeneous and homogeneous distribution in soil

1.9 Current and Potential Future Land Use

The current and potential future land use in the vicinity of the site under investigation is summarized in Table 1-6. This information taken from Holdren and Broomfield (2004) is needed later in the DQO process to support the evaluation of decision-error consequences.

Table 1-6. Land-use scenarios for the Idaho National Laboratory and Radioactive Waste Management Complex.

Time Period	Planned Land Use
Idaho National Laboratory	
Current to 2110	Industrial: active controlled access
2110 to 3010[a]	Assumed residential
Radioactive Waste Management Complex	
Current to 2110	Industrial: active controlled access
2110 to 3010[a]	Assumed nonresidential: passive controlled access

a. Specific land use scenarios beyond 2110 have not been defined and are only assumed as this point.

1.10 Preliminary Applicable or Relevant and Appropriate Requirements and Preliminary Remediation Goals

An abbreviated list of applicable or relevant and appropriate requirements (ARARs), PRGs, and other requirements that apply to OU 7-08 is presented in Table 1-7. The PRG is an action level or threshold value that provides the basis for choosing between alternative actions. The PRGs presented in Table 1-7 are based on modeling, regulatory thresholds, or risk. The final numerical action levels are set in DQO Step 5. Some discussion is provided below for each of the categories identified in Table 1-7.

Table 1-7. Abbreviated list of applicable or relevant and appropriate requirements, preliminary remediation goals, and other requirements applying to Operable Unit 7-08.

Media	ARARs	PRGs	Other Requirements
VOC Inventory Remaining in the Subsurface Disposal Area			
Shallow sedimentary soil	None	TBD	Engineering assessment value
VOC Contaminated Vadose Zone			
Vadose Zone			
Region A, Zone 1	None	118–190 ppmv CCl_4[a]	TETRAD fate and transport model—predicts compliance with groundwater protection RAOs
Region A, Zone 2		20–39 ppmv CCl_4[a]	
Region A, Zone 3		3–7 ppmv CCl_4[a]	
Region B, Zone 1		32–50 ppmv CCl_4[a]	
Region B, Zone 2		6–11 ppmv CCl_4[a]	
Region B, Zone 3		1–1.4 ppmv CCl_4[a]	
Groundwater			
SRPA	(40 CFR 141.61) Groundwater MCLs: CCl_4, 5 ppb TCA, 200 ppb TCE, 5 ppb PCE, 5 ppb	None	None

ARARs = applicable or relevant and appropriate requirements
MCL = maximum contaminant level
PCE = tetrachloroethene
PRG = preliminary remediation goal
RAO = remedial action objective
RG = remediation goal
SRPA = Snake River Plain Aquifer
TBD = to be determined
TCA = 1,1,1-trichloroethane
TCE=trichloroethene

a. PRG values were calculated only for CCl_4 because it is believed that the other COCs would have similar values and because CCl_4 concentrations are by far the highest of the COCs. It is anticipated that when RGs are achieved for CCl_4, the other COCs will be much less than their respective RGs.

1.10.1 Volatile Organic Compound Contaminated Vadose Zone

Original PRG values for the vadose zone provided in the OCVZ ROD (DOE-ID 1994) were developed using a simplified model and the PORFLOW simulation code. A more robust, multidimensional, multiphase model using the TETRAD simulation code has been developed since the ROD was issued, and it has been used to update the shallow PRGs and develop PRGs for the zones described in Section 1.6.6. A range of PRGs are listed for each zone because some conservatism was built into the derivation. The lower value represents the conservative estimate, while the higher value represents a more realistic estimate. Appendix C contains a complete discussion on how the PRG values were derived.

1.10.2 Groundwater

The groundwater value shown is the MCL for VOCs for a public water drinking system as established by the EPA (2002).

1.11 Statement of the Problem

1.11.1 Conceptual Site Model

The SDA received TRU contaminated waste from the Rocky Flats facility that was contaminated with oils and volatile organic solvents. Over time, the containers for these buried wastes released VOCs into the vadose zone under the SDA. The resulting organic waste plume has been detected from the ground surface to groundwater at a depth of approximately 177 m (580 ft) below ground surface.

The 1994 OU 7-08 ROD summarized the site assessment and identified the selected remedy: extraction and destruction of the organic contaminants from the vadose zone beneath and within the immediate vicinity of the RWMC. In addition, the selected remedy includes monitoring the vadose zone vapor and the SRPA. The objective of this selected remedy is to reduce the risks to human health and the environment associated with the organic contaminants present in the vadose zone and to prevent federal and state drinking water standards from being exceeded 100 years in the future outside the SDA boundary (see Section 1.6.8). A graphical representation of the conceptual site model is presented in Figure 1-12.

1.11.2 Data Quality Objective Approach

The seven-step DQO process developed by the EPA (1994) is being implemented for this project to support performance of the remedial alternative selected in the ROD by establishing a sampling design that meets the project objective to identify the environmental measurements necessary to determine when extraction and treatment can be terminated within the 100-year institutional control period (see Section 1.2).

1.11.3 Problem Statement

Given the goal of developing a sampling design that addresses the OCVZ project DQO, the problem is to clearly define the conceptual site model (see Figure 1-12) and determine the sampling requirements (type and frequency) and the associated constraints that may be used to support the decision-making process. The sampling design will need to address the unique aspects of the project objective and all applicable sampling protocols and guidance.

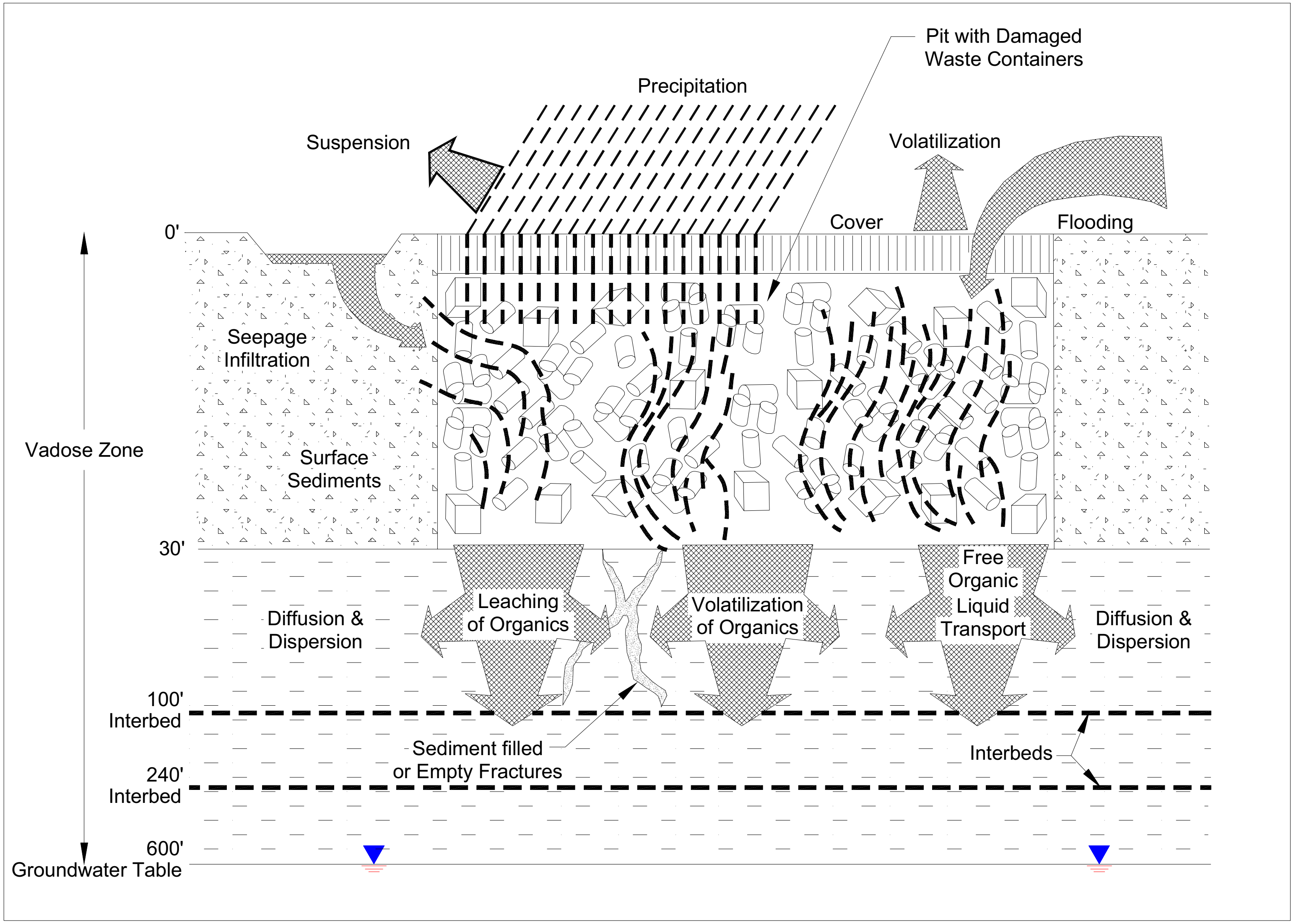


Figure 1-12. Graphical representation of the conceptual site model.

2. STEP 2—IDENTIFY THE DECISION

The purpose of DQO Step 2 is to define the principal study questions (PSQs) that must be resolved to address the problem identified in DQO Step 1 and the alternative actions that would result from the resolution of the PSQs. The PSQs and alternative actions then are combined into decision statements.

2.1 Principal Study Questions

The PSQs are fundamental to the DQO process. They require environmental measurements (e.g., physical, chemical, or radiological data) to resolve. The PSQs are presented in Table 2-1.

2.2 Alternative Actions

Alternative actions are those actions that could be taken after the PSQs have been resolved. They identify all of the possible appropriate actions that may be taken, including the alternative of taking no action. The alternative actions appropriate for the OCVZ project are listed in Table 2-2.

2.3 Decision Statements

The PSQs and alternative actions are combined into decision statements presented in Table 2-3 using the following format: "Determine whether [unknown environmental conditions, issues, or criteria from the PSQ] require (or support) [taking alternative actions]."

Decision Statements 2, 3, and 4 are interrelated. This also is true for Decision Statements 5, 6, and 7. Because the significance of these relationships is greater in the decision rules, the associated logic flow diagrams are presented in Step 5.

Table 2-1. Principal study questions for Operable Unit 7-08.

No.	Principal Study Question
1	Will the VOC inventory remaining in the SDA pits and the current and future rate of release from the active 743-series drums prevent the ultimate shutdown of the VVET system within the expected operational period?
2[b]	Do the vadose zone vapor monitoring results obtained from each of the zones in the Region A vapor plume (the portion within the influence or control of the current[a] VVET system) meet the RGs for the respective locations indicated by the fate and transport model during VVET system operations?
3[b]	Do the vadose zone vapor monitoring results obtained from each of the zones in the Region B vapor plume (the portion beyond the influence or control of the current[a] VVET system) meet the RGs for the respective locations indicated by the fate and transport model during VVET system operations?
4[b]	Do the results predicted by the VOC fate and transport model using analytical data obtained during VVET system operations from the combined Region A and B portions of the vapor plume indicate that the groundwater MCLs will be met after the 100-year institutional period?
5[c]	Do the vadose zone vapor monitoring results obtained from each of the zones within the Region A portion of the vapor plume during the compliance verification phase meet the RGs for the respective locations indicated by the fate and transport model?
6[c]	Do the vadose zone vapor monitoring results obtained from each of the zones within the Region B portion of the vapor plume during the compliance verification phase meet the RGs for the respective locations indicated by the fate and transport model?
7[c]	Do the results predicted by the VOC fate and transport model using analytical data obtained during the compliance verification phase from the combined Region A and B portions of the vapor plume indicate that the groundwater MCLs will be met after the 100-year institutional period?
8	Do the vadose zone vapor monitoring results obtained from each of the zones within the Region A and B portions of the vapor plume during the long-term monitoring phase meet the RGs for the respective locations indicated by the fate and transport model?
9	Do the results predicted by the VOC fate and transport model using analytical data obtained during the long-term monitoring phase from the combined Region A and B portions of the vapor plume indicate that the groundwater MCLs will be met after the 100-year institutional period?

MCL = maximum contaminant level
RG = remediation goal
SDA = Subsurface Disposal Area
VOC = volatile organic compound
VVET = vapor vacuum extraction with treatment

a. The current VVET system is defined as the configuration at the issuance of this document.
b. These principal study questions are interrelated. The relationship logic is carried forth into the decision statements.
c. These principal study questions are interrelated. The relationship logic is carried forth into the decision statements.

Table 2-2. Alternative actions.

Principle Study Question No.	No.	Alternative Action
1	1	The estimated VOC inventory remaining in the SDA pits and the current and future rate of release from the active 743-series drums may prevent the ultimate shutdown of the VVET system within the expected operational period. The project decision-makers will consider treatment or removal of the SDA source material to ensure protection of groundwater from VOC contamination.
1	2	The estimated VOC inventory remaining in the SDA pits and the current and future rate of release from the active 743-series drums may prevent the ultimate shutdown of the VVET system within the expected operational period. The project decision-makers will consider adoption of more aggressive remedial action alternatives to ensure protection of groundwater from VOC contamination. More aggressive remedial actions could include, but are not limited to, source treatment alternatives such as partial or full retrieval, in situ grouting, or in situ thermal treatment with shallow vapor extraction.
1	3	The estimated VOC inventory remaining in the SDA pits and the current and future rate of release from the active 743-series drums may prevent the ultimate shutdown of the VVET system within the expected operational period. The project decision-makers will consider operating the VVET system over a longer operating period to ensure protection of groundwater from VOC contamination.
1	4	The estimated VOC inventory remaining in the SDA pits and the current and future rate of release from the active 743-series drums is not projected to prevent the ultimate shutdown of the VVET system within the expected operational period. The project decision-makers determine that the VVET system may operate as planned until the requirements have been met for shutdown of the VVET system.
1	5	No action.
2	1	The vadose zone vapor monitoring results obtained during VVET system operations from each of the zones in the Region A vapor plume meet the RGs for the respective locations indicated by the fate and transport model. Evaluate PSQ 3.
2	2	The vadose zone vapor monitoring results obtained during VVET system operations from each of the zones in the Region A vapor plume do not meet the RGs for the respective locations indicated by the fate and transport model. The RAOs will not be satisfied, and VVET system operation must continue.
2	3	No action.

Table 2-2. (continued).

Principle Study Question No.	No.	Alternative Action
3	1	The vadose zone vapor monitoring results obtained from each of the zones in the Region B vapor plume meet the RGs for the respective locations indicated by the fate and transport model during VVET system operations. Evaluate PSQ 4.
3	2	The vadose zone vapor monitoring results obtained from each of the zones in the Region B vapor plume do not meet the RGs for the respective locations indicated by the fate and transport model during VVET system operations. The RAOs will not be satisfied. The project and decision-makers evaluate the expansion of the VVET system into Region B.
3	3	No action.
4	1	The results predicted by the VOC fate and transport model using analytical data obtained during VVET system operations from the combined Region A and B portions of the vapor plume indicate that the groundwater MCLs will be met after the 100-year institutional period. The RAOs have been satisfied. The VVET system will be evaluated for shutdown and start of the compliance verification phase.[a]
4	2	The results predicted by the VOC fate and transport model using analytical data obtained during VVET system operations from the combined Region A and B portions of the vapor plume indicate that the groundwater MCLs will not be met after the 100-year institutional period. The RAOs are not satisfied. The OCVZ project and decision-makers may evaluate continued operation of the current system or expansion of the VVET system.
4	3	No action.
5	1	The vadose zone vapor monitoring results obtained from each of the zones within the Region A portion of the vapor plume during the compliance verification phase meet the RGs for the respective locations indicated by the fate and transport model. Evaluate PSQ 6.
5	2	The vadose zone vapor monitoring results obtained from each of the zones within the Region A portion of the vapor plume during the compliance verification phase do not meet the RGs for the respective locations indicated by the fate and transport model. The RAOs will not be satisfied. The project and decision-makers evaluate the resumption of VVET system operations or expansion of the VVET system.
5	3	No action.

Table 2-2. (continued).

Principle Study Question No.	No.	Alternative Action
6	1	The vadose zone vapor monitoring results obtained from each of the zones within the Region B portion of the vapor plume during the compliance verification phase meet the RGs for the respective locations indicated by the fate and transport model. Evaluate PSQ 7.
6	2	The vadose zone vapor monitoring results obtained from each of the zones within the Region B portion of the vapor plume during the compliance verification phase do not meet the RGs for the respective locations indicated by the fate and transport model. The RAOs will not be satisfied. The project and decision-makers evaluate the expansion of the VVET system into Region B.
6	3	No action.
7	1	The results predicted by the VOC fate and transport model using analytical data obtained during the compliance verification phase from the combined Region A and B portions of the vapor plume indicate that the groundwater MCLs will be met after the 100-year institutional period. The RAOs have been satisfied. The project and decision-makers will evaluate the start of the long-term monitoring phase.[a]
7	2	The results predicted by the VOC fate and transport model using analytical data obtained during the compliance verification phase from the combined Region A and B portions of the vapor plume indicate that the groundwater MCLs will not be met after the 100-year institutional period. The RAOs will not be satisfied. The project and decision-makers evaluate the restart and expansion alternatives for the VVET system in both Regions A and B.
7	3	No action.
8	1	The vadose zone vapor monitoring results obtained from each of the zones within the Region A and B portions of the vapor plume during the long-term monitoring phase meet the RGs for the respective locations indicated by the fate and transport model. Evaluate PSQ 9.
8	2	The vadose zone vapor monitoring results obtained from each of the zones within the Region A and B portions of the vapor plume during the long-term monitoring phase do not meet the RGs for the respective locations indicated by the fate and transport model. The RAOs will not be satisfied. Evaluate PSQ 9. The project and decision-makers evaluate the restart and expansion alternatives for the VVET system in both Regions A and B.
8	3	No action.

Table 2-2. (continued).

Principle Study Question No.	No.	Alternative Action
9	1	The results predicted by the VOC fate and transport model using analytical data obtained during the long-term monitoring phase from the combined Region A and B portions of the vapor plume indicate that the groundwater MCLs will be met after the 100-year institutional period. The RAOs have been satisfied. The project and decision-makers determine that the long-term monitoring phase should continue.
9	2	The results predicted by the VOC fate and transport model using analytical data obtained during the long-term monitoring phase from the combined Region A and B portions of the vapor plume indicate that the groundwater MCLs will not be met after the 100-year institutional period. The RAOs will not be satisfied. The project and decision-makers evaluate the restart and expansion alternatives for the VVET system in both Regions A and B.
9	3	No action.

MCL = maximum contaminant level
RG = remediation goal
PSQ = principal study question
SDA = Subsurface Disposal Area
VOC = volatile organic compound
VVET = vapor vacuum extraction with treatment

a. Principal Study Questions 5 and 8 must satisfy other considerations as well, as indicated in Section 1.6.6.

Table 2-3. Decision statements.

No.	Decision Statement
1	Determine whether the estimated VOC inventory remaining in the SDA pits and the current and future rate of release from the active 743-series drums may prevent the ultimate shutdown of the VVET system within the expected operational period, thereby requiring consideration of more aggressive remedial actions than currently planned for the OCVZ project.
2	Determine whether the vadose zone vapor monitoring results obtained during VVET system operations from the Region A portion of the vapor plume meet the RGs for the respective locations indicated by the fate and transport model, enabling the VVET system to be evaluated for shutdown. Evaluate Decision Statement 3.
3	Determine whether the vadose zone vapor monitoring results obtained during VVET system operations from the Region B portion of the vapor plume meet the RGs for the respective locations indicated by the fate and transport model, enabling the VVET system to be evaluated for shutdown. Evaluate Decision Statement 4.
4	Determine whether the results predicted by the VOC fate and transport model using analytical data obtained during VVET system operations from the combined Region A and B portions of the vapor plume indicate that the groundwater MCLs will be met after the 100-year institutional period, enabling the VVET system to be evaluated for shutdown.

Table 2-3. (continued).

No.	Decision Statement
5	Determine whether the vadose zone vapor monitoring results obtained from each of the zones within the Region A portion of the vapor plume during the compliance verification phase meet the RGs for the respective locations indicated by the fate and transport model, enabling the VVET system to be evaluated for long-term shutdown. Evaluate Decision Statement 6.
6	Determine whether the vadose zone vapor monitoring results obtained from each of the zones within the Region B portion of the vapor plume during the compliance verification phase meet the RGs for the respective locations indicated by the fate and transport model, enabling the VVET system to be evaluated for long-term shutdown. Evaluate Decision Statement 7.
7	Determine whether the results predicted by the VOC fate and transport model using analytical data obtained during the compliance verification phase from the combined Region A and B portions of the vapor plume indicate that the groundwater MCLs will be met after the 100-year institutional period, enabling the VVET system to be evaluated for long-term shutdown.
8	Determine whether the vadose zone vapor monitoring results obtained from each of the zones within the Region A and B portions of the vapor plume during the long-term monitoring phase meet the RGs for the respective locations indicated by the fate and transport model, enabling the vadose zone system to be evaluated for continuation in the long-term shutdown mode. Evaluate Decision Statement 9.
9	Determine whether the results predicted by the VOC fate and transport model using analytical data obtained during the long-term monitoring phase from the combined Region A and B portions of the vapor plume indicate that the groundwater MCLs will be met after the 100-year institutional period, enabling the vadose zone system to be evaluated for continuation in the long-term shutdown mode.

MCL = maximum contaminant level
OCVZ = organic contamination in the vadose zone
RG = remediation goal
SDA = Subsurface Disposal Area
VOC = volatile organic compound
VVET = vapor vacuum extraction with treatment

3. STEP 3—IDENTIFY INPUTS TO THE DECISION

3.1 Information Required to Resolve Decision Statements

The data required to resolve each of the decision statements identified in Table 2-3 are specified in Table 3-1; whether the data already exist is also indicated. For the data identified as existing, the source references are provided with a qualitative assessment whether the data quality is sufficient to resolve the corresponding decision statement.

Sondrup et al. (2004) attempted to estimate the remaining VOC mass required to support Decision Statement 1 in Table 2-3. Although the uncertainty could not be rigorously quantified, even the lowest estimates indicate that there is likely sufficient VOC waste remaining to extend VVET operations beyond the expected operational period. However, ARP Phase I is currently retrieving waste material from an area of Pit 4, and construction of Phase II facilities, which cover parts of Pits 4 and 6, has begun. Approximately 49% of the original CCl_4 inventory was buried in the ARP I and ARP II areas and another 11% was buried in the remaining targeted areas. If ARP I and II are completed, it is reasonable to assume that approximately one-half of the VOC waste that remains will be removed. In that case, release rate information used to support Decision Statement 1 will be necessary only in non-targeted ARP areas that contain VOCs. In targeted areas such as ARP I and ARP II, it may be necessary to verify that releases are minimal. See Section 1.6.5 for a more complete description of ARP.

3.2 Computational, Survey, and Sampling and Analysis Methods

The decision statements identified in Table 2-3 that cannot be resolved are listed in Table 3-1. They cannot be resolved because either the data required to resolve them do not exist or the data are of insufficient quality. For these decision statements, computational, surveying, and sampling and analysis methods that could be used to obtain the required data are presented in Table 3-2.

Each of the survey and analytical methods that may be used to provide the required information to resolve each of the decision statements is identified in Table 3-3. The possible limitations associated with each of these methods are also provided with the estimated cost.

3.3 Analytical Performance Requirements

The analytical performance requirements for the data that must be collected to resolve each of the decision statements are defined in Table 3-4. These performance requirements include the practical quantitation limit and precision and accuracy requirements for each of the COCs.

Table 3-1. Required information and reference sources for the decision statements in Table 2-3.

Decision Statement No.	Required Data	Do Data Exist?	Source Reference	Is Quality Sufficient?	Is Additional Information Required?
1	VOC mass remaining in source material.	Yes	Sondrup et al. (2004)	Yes[a]	No
	Rate of release of VOCs from source material	No	Not available	Not applicable	Yes[b]
2 through 4	Vadose zone organic vapor concentrations during VVET operations.	Yes	Vapor monitoring documents in Table 1-1[c]	No[c]	Yes
	Groundwater concentrations[c]	Yes	Groundwater monitoring documents in Table 1-1[c]	No[d]	Yes[d]
5 through 7	Vadose zone organic vapor concentrations during the compliance verification phase (background VOC concentrations and rebound).	No	Not available	Not applicable	Yes
	Groundwater concentrations[d]	No	Not available	No[d]	Yes[d]
8, 9	Vadose zone organic vapor concentrations during the long-term monitoring phase (background VOC concentrations and rebound).	No	Not available	Not applicable	Yes
	Groundwater concentrations[d]	No	Not available	No[d]	Yes[d]

VOC = volatile organic compound
VVET = vapor vacuum extraction with treatment

a. Sondrup et al. (2004) attempted to estimate the amount of VOC mass remaining using two methods. Although the uncertainty of the methods could not be rigorously quantified, it is believed that even the lower bound was sufficient to extend operation of the VVET system beyond the expected operational period (see Decision Statement 1). Because of this, and because ARP plans to remove the majority of the remaining VOC waste, only the release rate portion of Decision Statement 1 remains to be answered.

b. Release rate information will be necessary in non-targeted ARP areas that contain VOCs. In targeted areas such as ARP I and ARP II, it may only be necessary to verify that releases are minimal.

c. The data that exist have not been collected from the proper period required to resolve the issues in the decision statements. Therefore, this table concludes that additional sampling is required.

d. Groundwater data support fate and transport model development and confirm model predictions.

Table 3-2. Information required to resolve decision statements (see Table 2-3).

Decision Statement No.	Required Data	Computational Methods	Survey or Analytical Methods
1	Shallow VOC vapor concentrations	Not available	Analysis of shallow soil gas samples
2 through 9	Vadose zone organic vapor concentrations	TETRAD	Vapor sampling and laboratory analysis
	Groundwater concentrations	TETRAD	Groundwater sampling and analysis

VOC = volatile organic compound
VVET = vapor vacuum extraction with treatment

Table 3-3. Potentially appropriate survey and analytical methods to resolve decision statements (see Table 2-3).

Decision Statement No.	Contaminants of Concern	Potentially Appropriate Survey or Analytical Method	Possible Limitation	Cost
1	Vapor analysis for CCl_4, TCA, TCE, and PCE	EPA Method TO-14	None identified	Comparable to EPA Method 8021 costs
		Brüel and Kjær multi-gas photoacoustic instrument	Lack of lab quality assurance and quality control prevents use for VVET shutdown decisions	Low
2 through 9	Vapor analysis for CCl_4, TCA, TCE, and PCE	EPA Method TO-14	None identified	Comparable to EPA Method 8021 costs
		Brüel and Kjær multi-gas photoacoustic instrument	Lack of lab quality assurance and quality control prevents use for VVET shutdown decisions	Low
	Groundwater analysis for CCl_4, TCA, TCE, and PCE	EPA Method 8021 (GC)	None identified	Potentially less costly than EPA Method 8260B
		EPA Method 8260B (GC/MS)	None identified	Moderate

EPA = U.S. Environmental Protection Agency
GC = gas chromatography
GC/MS = gas chromatography/mass spectrometry
PCE = tetrachloroethene
TCA = 1,1,1-trichloroethane
TCE = trichloroethene
VVET = vapor vacuum extraction with treatment

Table 3-4. Analytical performance requirements to resolve decision statements (see Table 2-3).

Decision Statement No.	Contaminants of Concern	Analytical Method	Preliminary Action Level	Practical Quantitation Limit	Precision Requirement (% Recovery)	Accuracy Requirement (% RPD or RPD)
Performance Requirements for Laboratory Measurements						
1 through 9	Vapor; CCl_4, TCA, TCE, PCE	TO-14[a]	1 ppmv[b]	.001 to .005 ppmv	±30	70 to 130
2 through 9	Groundwater; CCl_4, TCA, TCE, PCE	EPA Method 8021B (GC)	CCl_4, 5 ppb TCA, 200 ppb TCE, 5 ppb PCE, 5 ppb	1 to 5 ppb	(c)	(c)
		EPA Method 8260B (GC/MS)		1 to 5 ppb	(c)	(c)
Performance Requirements for On-Site Laboratory and Field Measurements						
1 through 9	Vapor analysis for CCl_4, TCA, TCE, PCE	Brüel and Kjær Method 1302 photo-acoustic instrument	1 ppmv	1 ppmv	±30	80 to 120

EPA = U.S. Environmental Protection Agency
GC = gas chromatography
GC/MS = gas chromatography/mass spectrometry
PCE = tetrachloroethene
RPD = relative percent difference
TBD = to be determined
TCA = 1,1,1-trichloroethane
TCE = trichloroethene

a. Chloroform also will be reported from this analysis for tracking purposes but is not retained as a contaminant of concern.
b. This is not an action level. It is the minimum value determined adequate for volatile organic compound fate and transport model use.
c. Precision and accuracy requirements are defined by the analytical method.

4. STEP 4—DEFINE THE BOUNDARIES OF THE STUDY

The primary objective of DQO Step 4 is to identify the population of interest, define the spatial and temporal boundaries that apply to each decision statement, define the scale of decision-making, and identify any practical constraints (hindrances or obstacles) that must be taken into consideration in the sampling design. This step is intended to ensure that the sampling design will result in the collection of data that accurately reflect the condition of the site.

4.1 Population of Interest

The populations of interest that apply to each decision statement in Table 2-3 are defined in Table 4-1. The intent of Table 4-1 is to establish clear definitions of the attributes that make up each population of interest by stating them in a way that makes the focus of the study unambiguous.

Table 4-1. Characteristics that define the population of interest to resolve decision statements (see Table 2-3).

Decision Statement No.	Population of Interest
1	Contaminant of concern vapor concentrations located above known VOC hot spots (i.e., areas with high levels of contamination)
2, 4, 5, 7, 8, 9	The portion of the VOC vapor plume that is within the influence or control of the current VVET system[a]
	The SRPA under vapor monitoring wells that support modeling
3, 4, 6, 7, 8, 9	The portion of the VOC vapor plume that is beyond the influence or control of the current VVET system[a]
	The SRPA under vapor monitoring wells that support modeling.

SRPA = Snake River Plain Aquifer
VOC = volatile organic compound
VVET = vapor vacuum extraction with treatment

a. The decision statement assignments for these populations overlap.

As shown in Table 4-1, two different portions, constituting populations, within the OCVZ vapor plume apply to the VVET shutdown decision. One portion of the vapor plume is within the influence of the current VVET system (designated Region A). The second portion is beyond the influence of the current VVET system (designated Region B). The significance of these regional distinctions to the decision-making process is described in the discussion that follows. A simplified graphical representation of Regions A and B is provided in Figure 4-1.

The decision to shut down the VVET system initially will focus on the vapor concentrations within Region A (the region being influenced by the VVET system). This is because measured vapor concentrations within Region A provide a clear indication that the VVET system must continue operating or may be considered for shutdown. However, because the VVET shutdown decision is linked to protection of groundwater under vapor monitoring wells that support modeling, some portion of the region that extends beyond the limits of Region A also is significant. Therefore, the basis for the shutdown decision is a two-step evaluation. The requirements that must be satisfied are as follows:

- The measured concentrations within Region A and B must meet their respective RGs
- The fate and transport model will be used to predict SRPA groundwater concentrations using both Region A and B vapor data.

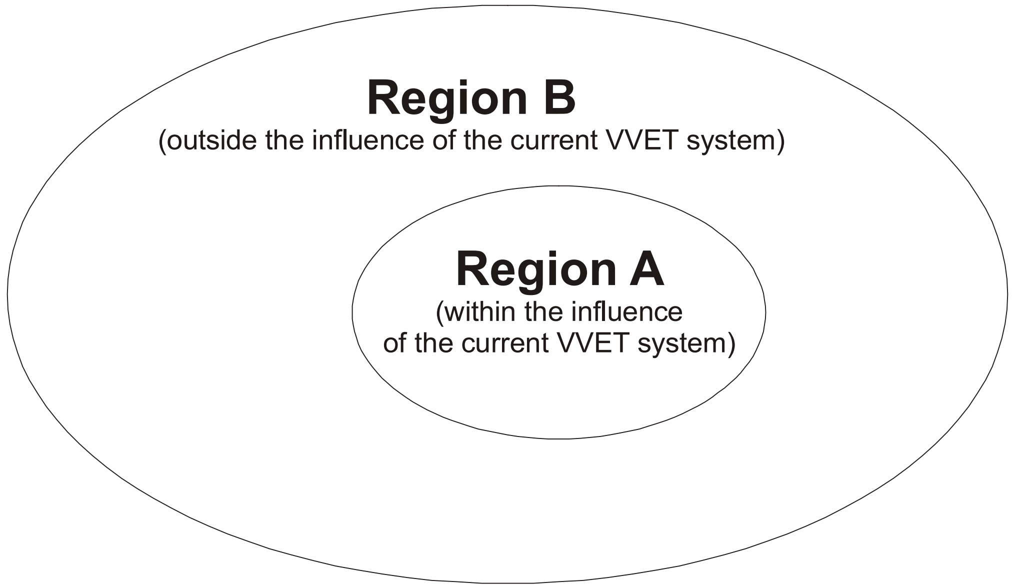


Figure 4-1. Populations of interest for the vapor vacuum extraction with treatment system shutdown decision.

Step-wise approach is essential to prevent decision errors. Two potential decision errors could develop if both regions are not considered. Two scenarios are used to illustrate. In Scenario 1, the erroneous decision is unnecessary operation of the VVET system. Scenario 2 shows the case for which the VVET system is prematurely shut down.

4.1.1 Scenario 1

In Scenario 1, the VVET shutdown decision is assumed to be based solely on fate and transport modeling to estimate groundwater concentrations using vapor data from all of the monitoring wells in and around the SDA. In Scenario 1, the vapor concentrations within Region A could be reduced to the practical limits of the VVET system. However, the residual vapor concentrations in Region A and the additional vapor mass in Region B could be sufficient to cause the model to predict that the groundwater concentrations will exceed the MCLs. Thus, the decision to continue system operations would be erroneous because the VVET system would have reached its practical limit of performance.

4.1.2 Scenario 2

In Scenario 2, the VVET system shutdown decision is assumed to be based on evaluation of measured vapor concentrations against the RGs from Regions A and B. Fate and transport modeling would not be used. Using this approach could lead to the RGs being met uniquely for each region. However, the cumulative effect of the vapor mass in Regions A and B may be sufficient to cause the groundwater MCLs to be exceeded after the 100-year institutional period. Therefore, ignoring the cumulative plume impact could result in a premature shutdown decision, possibly leading to unacceptable groundwater contamination levels.

Therefore, Regions A and B are the two populations that will be evaluated further in this DQO study.

4.2 Geographical Boundaries

The geographic boundaries that apply to each decision statement are identified in Table 4-2. Limiting the geographic boundaries of the study area ensures that the investigation does not expand beyond the original scope of the task.

Table 4-2. Geographic boundaries of the investigation to resolve decision statements (see Table 2-3).

Decision Statement No.	Geographic Boundaries of the Investigation
1	Within the Subsurface Disposal Area boundary
2 through 9	Within and around the Subsurface Disposal Area boundary
	Snake River Plain Aquifer under and around the Subsurface Disposal Area

4.3 Zones with Homogeneous Characteristics

The zones under investigation within OU 7-08 that have relatively homogeneous characteristics are defined in Table 4-3. These zones were identified by using existing information to segregate the elements of the population into subsets that exhibit relatively homogeneous characteristics (e.g., types of contaminants). The site is broken into zones based on contaminant spread, constituency of contamination, resulting contaminant concentration, and the probability of future contamination. This homogeneity does not imply any uniformity of geologic strata. Dividing the site into separate zones reduces the overall complexity of the problem, thereby simplifying the decision-making process.

4.4 Spatial Scale of Decision-Making

The spatial scale of decision-making that may apply to each of the decision statements is identified in Table 4-4. The EPA guidance document for the DQO process (EPA 1994) defines the spatial scale of decision-making as the smallest, most appropriate subset of the population (or subpopulations) for which decisions will be made based on the spatial boundaries. The approach used to determine those populations for the OCVZ project decisions is described in the subsections below.

4.4.1 Decision Statements 2 through 9 (Vadose Zone Vapor Monitoring)

The spatial scale of decision-making is a step to further define the population of interest for monitoring and decision-making purposes. Decision Statements 2 through 9 (see Table 2-3) are unique in that the VVET shutdown decision will be based on measured vapor concentrations through a fate and transport model that predicts VOC concentrations in groundwater in the future. As discussed in Section 4.1, two regions of interest apply to the VVET shutdown decision-making process.

4.4.1.1 Region A. As clearly shown in Figures 1-4 and 1-5, the VVET system has had a favorable impact on the underlying vapor plume over a 9-year operating period. However, the absolute limit of the influence of the current VVET system on the underlying VOC plume is not known at this time. Because the EPA DQO guidance (EPA 1994) allows the spatial scale of decision-making to be a subset of a population, defining the exact limits of the VVET system influence is unnecessary. The spatial scale of decision-making will in this case be a reference boundary (a subset) within the actual limit of VVET influence. The boundary for this spatial scale of decision-making will be a line that circumscribes the vapor monitoring wells that have been determined to be within the area of influence of the current VVET system. The vapor-monitoring data obtained from within this subset population will be used to support

Table 4-3. Zones with homogenous characteristics for resolving decision statements in Table 2-2.

Decision Statement No.	Population of Interest	Zone	Homogeneous Characteristic Logic
1	Shallow soil gas concentrations of COCs above known VOC hot spots	Shallow soils above buried waste	Soil gas measurements in hot spot locations.
2, 4, 5, 7, 8, 9	The portion of the VOC plume (as indicated by CCl_4) that may be influenced or controlled by the current VVET system	Region A, RG Zone 1 (see Figure 4-2)	The three-dimensional zone that is being affected by operation of the current VVET system. This zone is within Region A from ground surface to the 33.5-m (110-ft) B-C interbed. As the uppermost RG zone, it has the highest allowable vapor concentrations (and the least sensitivity to groundwater impact).
		Region A, RG Zone 2 (see Figure 4-2)	This zone was not affected by the original VVET system, but is being affected by the current system due to additional extraction wells. It is a three-dimensional zone immediately below Region A, Zone 1. Sedimentary interbeds at the 33.5-m (110-ft) B-C and 73-m (240-ft) C-D elevations below ground surface vertically define Zone 1. The second RG zone has the second level of allowable vapor concentrations (moderate groundwater impact sensitivity).
		Region A, RG Zone 3 (see Figure 4-2)	This three-dimensional zone is below Region A, Zone 2. The VVET system has recently been expanded to be able to extract from this zone. The zone extends from below the 73-m (240-ft) C-D interbed to groundwater. It has low allowable vapor concentrations (highest groundwater impact sensitivity).
	The measurable extent of the SRPA under and around the SDA	Groundwater	Groundwater potentially contaminated from vadose zone vapors under Region A.

Table 4-3. (continued).

Decision Statement No.	Population of Interest	Zone	Homogeneous Characteristic Logic
3, 4, 6, 7, 8, 9	The portion of the VOC vapor plume (as indicated by CCl_4) beyond the influence or control of the current VVET system	Region B, RG Zone 1 (see Figure 4-2)	This is the uppermost three-dimensional zone in Region B. It is outside the direct influence or control of the current VVET system. This zone extends from ground surface to the 33.5-m (110-ft) B-C interbed. The uppermost RG zone has the highest allowable vapor concentrations (least groundwater impact sensitivity).
		Region B, RG Zone 2 (see Figure 4-2)	A three-dimensional zone immediately below Region B, Zone 1, and extending from the 33.5-m (110-ft) B-C interbed to the 73-m (240-ft) C-D interbed. The second RG zone has moderate levels of allowable vapor concentrations (moderate groundwater impact sensitivity).
		Region B, RG Zone 3 (see Figure 4-2)	This three-dimensional zone includes the deep vadose zone monitoring wells in Region B with vapor monitoring capability. This RG zone extends from below the 73-m (240-ft) C-D interbed to groundwater. It has low allowable vapor concentrations (highest groundwater impact sensitivity).
	The measurable extent of the SRPA under and around the SDA	Groundwater	Groundwater potentially contaminated from vadose zone vapors under Region B.

COC = contamination of concern
RG = remediation goal
SDA = Subsurface Disposal Area
SRPA = Snake River Plain Aquifer
VOC = volatile organic compound
VVET = vapor vacuum extraction with treatment

Table 4-4. Spatial scale of decision-making.

Decision Statement No.	Spatial Scale
1	Measurable vapor concentrations above buried waste
2, 4, 5, 7, 8, 9	Region A, RG Zone 1—A reference boundary line that circumscribes certain vapor monitoring wells within the region of influence or control of the current VVET system from the ground surface to the 33.5-m (110-ft) B-C interbed (see Figure 7-3).
	Region A, RG Zone 2—A border around the vadose zone vapor monitoring wells that can sample from within RG Zone 2 (from the 33.5-m [110-ft] B-C depth to the 73-m [240-ft] C-D depth) (see Figure 7-4).
	Region A, RG Zone 3—A border around vadose zone vapor monitoring wells that extends into RG Zone 3 (from below the 73-m [240-ft] C-D interbed) (see Figure 7-4).
3, 4, 6, 7, 8, 9	Region B, RG Zone 1—A region that begins laterally at the Region A, Zone 1, spatial scale of decision-making boundary line out to a boundary described by the outermost OCVZ vapor monitoring wells. It extends vertically from the ground surface to the 33.5-m (110-ft) B-C interbed (see Figure 7-3).
	Region B, RG Zone 2—A region that begins laterally at the Region A, Zone 2, spatial scale of decision-making boundary line to a boundary described by the outermost OCVZ vapor monitoring wells. The vertical boundary extends from the 33.5-m (110-ft) B-C interbed to the 73-m (240-ft) C-D interbed (see Figure 7-4).
	Region B, RG Zone 3—A region that begins laterally at the Region A, Zone 3, spatial scale of decision-making boundary line to a boundary described by the outermost OCVZ vapor monitoring wells. This zone extends from below the 73-m (240-ft) C-D interbed to groundwater (see Figure 7-4).

OCVZ = organic contamination in the vadose zone
RG = remediation goal
VOC = volatile organic compound
VVET = vapor vacuum extraction with treatment

4.4.1.2 Region A, RG Zone 1, Decision-making. The spatial scales of decision-making are shown conceptually in Figure 4-2 for all regions and RG zones. A boundary of the spatial scale of decision-making for Region A, Zone 1, is shown in Figure 7-3 (see Section 7) as a dashed boundary line on a map of the RWMC. The boundary line shown in Figure 7-3 was determined from engineering judgment, rather than a statistical analysis of the vapor monitoring data from the wells within the SDA.

The spatial scale of decision-making for RG Zone 2 is not based on VVET influence because until just recently, viable extraction wells in this zone did not exist. The basis for this spatial scale of decision-making boundary, therefore, is a border described by the location of vadose zone monitoring wells within RG Zone 2 (from the 33.5-m [110-ft] B-C depth to the 73-m [240-ft] C-D depth). When sufficient vapor data collected from Zone 2, since expansion of the VVET system into this zone exists, it should be analyzed so the spatial scale of decision-making for that zone can be determined in the same manner as for Zone 1.

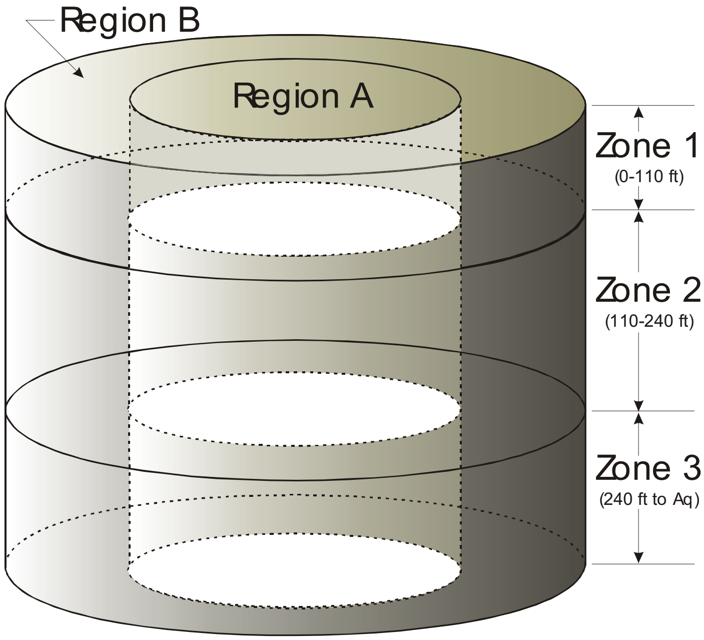


Figure 4-2. Conceptual spatial scales of decision-making for the vapor vacuum extraction with treatment shutdown decisions for all preliminary remediation goal zones within Regions A and B.

The outer limit of the spatial scale of decision-making for RG Zone 3 is a boundary that will be defined by the location of existing and recently constructed deep vadose zone monitoring and extraction wells within RG Zone 3 (below the 73-m (240-ft) C-D interbed to groundwater). Although the VVET system has recently been expanded into this zone, it has not yet been utilized. When the VVET system in RG Zone 3 is utilized, the spatial scale of decision-making for that zone should be determined in the same manner as for Zone 1. The spatial scales of decision-making boundaries for Region A, Zones 2 and 3, are shown in Section 7 (see Figures 7-2 and 7-3).

4.4.1.3 Region B. The spatial scales of decision-making for Region B rely on three RG zones, but with some detail differences from those used in Region A.

The spatial scales of decision-making for all zones within Region B are outside the area of influence of the current VVET system. The lateral boundary for all Region B spatial scales of decision-making is from the Region A spatial scale of decision-making boundary to the outermost boundary defined by vapor monitoring wells used for modeling within the OCVZ system. The first spatial scale of decision-making is the Region B, RG Zone 1, which extends from the ground surface to the 33.5-m (110-ft) B-C interbed. The next is RG Zone 2, which extends from below the 33.5-m (110-ft) B-C interbed to the 73-m (240-ft) C-D interbed within the lateral boundaries of Region B. The third spatial scale of decision-making is RG Zone 3, which is a boundary around the deep wells within Region B that have vapor monitoring capability below the 73-m (240-ft) C-D interbed. The spatial scales of decision-making for Region B for all RG zones are depicted conceptually in Figure 4-2. (The inner and outer boundaries of the spatial scales of decision-making for Region B are shown in plan view maps of the RWMC in Figures 7-3 and 7-4.)

4.5 Temporal Boundaries

Temporal boundaries that may apply to each decision statement listed in Table 2-2 are identified in Table 4-5. The temporal boundary refers to both the timeframe over which each decision statement applies (e.g., number of years) and when (e.g., season, time of day, and weather conditions) the data should optimally be collected.

Table 4-5. Temporal boundaries of the investigation for resolving decision statements (see Table 2-3).[a]

Decision Statement No.	Timeframe	When to Collect Data
1	Soil gas surveys—The data will be used to reflect changing VOC concentrations over a period of time sufficient to perform a trend analysis.	Annual or biennial sampling over a several-year period as needed. The ultimate frequency will be determined by the results of previous surveys.
2 through 4	The vapor monitoring data may be collected only during the VVET operating period, but is used to predict groundwater concentrations beyond the 100-year institutional control period.	During VVET operations, until the compliance verification phase, and during the short-term rebound periods (annual) within the VVET operating period.
5 through 7	The vapor monitoring data are meaningful only during the compliance verification period but are used to predict groundwater concentrations beyond the 100-year institutional control period.	During the compliance verification period.
8, 9	Vapor monitoring data obtained in the long-term monitoring phase.	After the ultimate shutdown decision.

VOC = volatile organic compound
VVET = vapor vacuum extraction with treatment

a. The temporal values in this table will be revised in Step 5 after development of the statistical parameters of interest.

Several temporal factors are related to vapor monitoring for the VVET shutdown decisions. These, as noted in Table 4-5, include the following:

- **Sampling During VVET Operations—**The discussion in Section 4.1 points to the need for sampling during VVET operations to support the shutdown decision. The vapor concentrations will be monitored on a monthly basis during VVET system operations.

- **Sampling During Short-Term Rebound Periods—**The VVET systems will not be operated continuously. The OCVZ project plans to shut down all VVET systems periodically for short-term rebound periods to monitor and evaluate the vadose zone rebound response.

The rebound response is significant to the shutdown decision because it may provide an early indication of the vadose zone rebound behavior during the compliance verification phase. If the rebound response were not monitored, the project could mistakenly begin the compliance verification phase prematurely, resulting in an unplanned and untimely restart of the VVET system. This must be avoided because of the high costs and administrative and engineering requirements associated with restart of the VVET system after extended shutdown periods.

Sampling During Compliance Verification Phase—Monitoring performed during the compliance verification phase will provide the information necessary to decide whether the system requires restarting or whether the system can be shut down, initiating the long-term monitoring phase.

Long-Term Monitoring Phase—This is the last phase planned for the OCVZ project. It is initiated after the final VVET shutdown decision has been made. The VVET systems would be mothballed, and long-term vapor monitoring would begin at lower frequency than during the operations or compliance verification phases. Data obtained during this phase will be used to verify that the vadose zone VOC concentrations remain within allowable limits or that restart of the VVET system may be necessary.

4.6 Scale of Decision-Making

In Table 4-6, the spatial and temporal scales of decision-making have been summarized for each decision statement.

Table 4-6. Scale of decision-making for decision statements (see Table 2-3).

Decision Statement No.	Population of Interest	Spatial Scale of Decision-Making	Temporal Scale of Decision-Making[a]
1	Shallow soil gas concentrations of COCs from known VOC hot spots.	Shallow soils immediately above VOC burial locations.	The surveys should be performed at or around the same time of the year, preferably during the summer months.
2, 4, 5, 7, 8, 9	The portion of the VOC vapor plume (as indicated by CCl_4) within the influence or control of the current VVET system.	**Region A, RG Zone 1**—A reference boundary line that circumscribes certain vapor monitoring wells within the region of influence or control of the current VVET system from the ground surface to the 33.5-m (110-ft) B-C interbed. (See Figure 7-3, which shows a preliminary boundary line for RG Zone 1. This boundary may be redefined after statistical analysis of the vapor data.) **Region A, RG Zone 2—**A border around vadose zone vapor monitoring wells that can sample from within RG Zone 2 (from the 33.5-m [110-ft] B-C depth to the 73-m [240-ft] C-D depth). (A boundary line for Zone 2 is shown in Figure 7-4.) **Region A, RG Zone 3—**A border around vadose zone vapor monitoring wells that extend into RG Zone 3 (from below the 73-m [240-ft] C-D interbed). (See Figure 7-4).	Sampling During VVET Operation (Decision Statements 2 through 4). Sampling during the short-term rebound periods (Decision Statements 2 through 4). Sampling during compliance verification phase (Decision Statements 5 through 7). Sampling during the long-term monitoring period (Decision Statements 8 and 9).

Table 4-6. (continued).

Decision Statement No.	Population of Interest	Spatial Scale of Decision-Making	Temporal Scale of Decision-Making[a]
3, 4, 6, 7, 8, 9	The portion of the VOC vapor plume (as indicated by CCl_4) that is beyond the influence or control of the current VVET system.	**Region B, RG Zone 1—**A region that begins laterally at the Region A, Zone 1 spatial scale of decision-making boundary line out to a boundary described by the outermost OCVZ vapor monitoring wells. It extends vertically from the ground surface to the 33.5-m (110-ft) B-C interbed (see Figure 7-3). **Region B, RG Zone 2—**A region that begins laterally at the Region A, Zone 2 spatial scale of decision-making boundary line to a boundary described by the outermost OCVZ vapor monitoring wells. The vertical boundary extends from the 33.5-m (110-ft) B-C interbed to the 73-m (240-ft) C-D interbed (see Figure 7-4). **Region B, RG Zone 3—**A region that begins laterally at the Region A, Zone 3 spatial scale of decision-making boundary line to a boundary described by the outermost OCVZ vapor monitoring wells. This zone extends from below the 73-m (240-ft) C-D interbed to groundwater (see Figure 7-4).	Sampling during VVET operations (Decision Statements 2 through 4). Sampling during compliance verification phase (Decision Statements 5 through 7). Sampling during the long-term monitoring period (Decision Statements 8 and 9).

COC = contaminant of concern
OCVZ = organic contamination in the vadose zone
RG = remediation goal
SDA = Subsurface Disposal Area
VOC = volatile organic compound
VVET = vapor vacuum extraction with treatment

a. The temporal values in this table will be enhanced in Step 5 after development of the statistical parameters of interest.

4.7 Practical Constraints

This section contains practical constraints that may impact data collection such as physical barriers, difficult sample matrices, high-radiation areas, or other conditions that must be considered in the design and scheduling of the sampling program.

In the original DQO report, the only constraints listed were the lack of deep vadose zone vapor sampling capabilities and groundwater sampling wells within the SDA. The lack of deep vadose zone vapor sampling capabilities is no longer a constraint due to the recent addition of five wells with vapor sampling capabilities in the deep vadose zone (below the 73-m [240-ft] C-D interbed). Groundwater sampling within the SDA, however, is still limited to only one well.

5. STEP 5—DEVELOP A DECISION RULE

The intent of DQO Step 5 is to develop a decision rule for each decision statement in the form of an "IF…THEN…" statement that incorporates the statistical parameter of interest, the scale of decision-making, the action level, and any alternative actions that would result from resolution of the decision.

5.1 Inputs Needed to Develop Decision Rules

For each decision statement, the corresponding statistical parameter of interest (e.g., mean, maximum, 95% UCL) that supports formulation of the decision rules is established in Table 5-1.

The statistical parameters applied to the soil gas measurements (mean and median) are useful for estimating the central points of tendency (point intervals) for many or few data points. In addition, shallow soil gas trends will be evaluated over time.

Certain temporal considerations are defined in Table 5-1. The trend parameter used for several of the decision statements requires approximately 10 sampling events to establish meaningful results. Because the project will not accept trending periods for the VVET shutdown decisions with less than 1 year's data, a monthly sampling interval was selected to meet sampling frequency requirements for the trend analyses. While a monthly sampling interval is a reasonably good choice, it does not guarantee data independence as is required by the trending method. Therefore, monitoring data collected since installation of the extraction system will be used to optimize sampling frequency from existing and new installations and configurations. Trend analyses are discussed in greater detail in Appendices A and B.

In addition to the trend analysis and the 95% UCL performed on the monitored data within the RG zones, the project also may calculate the 95% UCL of the mean, lognormal mean, or median (as appropriate) values for the individual sample locations over time. This calculation allows the project to focus attention on individual well locations and sampling ports where RGs have been exceeded over time. This statistic is not identified as a decision-making driver, but can be used as a tool for tracking localized system performance.

Control charts are statistical tools that may be used to analyze the data accumulated during the compliance verification phase. These charts are discussed in Appendix B. The project technical representatives, using data obtained during the VVET operational and short-term shutdown periods, will base the control chart limits on observed data. The number of short-term shutdown periods necessary to establish control chart limits will be determined by the project as the VVET operations database is established.

The scales of decision-making identified in Step 4 are specified in Table 5-2.

The sampling designs for the shallow soil gas surveys were developed judgmentally by the DQO team because the sampling frequencies were not driven by the statistical parameters of interest. Soil gas surveys have been proposed to detect changes in release rate from source areas not impacted by ARP waste retrieval activities. To see changes in release rates that are not seasonal, an annual or biennial sampling frequency over a several-year period is recommended. Although the Kendall test has not been proposed for soil gas survey data, it could be used so long as efforts are made to perform each survey under the same type of conditions. The need (in terms of location) and schedule for this sampling will be based on the amount of waste retrieved by ARP and the results of the initial surveys. Surveys should be performed over all VOC source areas focusing first on areas not impacted by ARP. Targeted areas impacted by ARP should require minimal surveying to confirm that releases are small.

Table 5-1. Statistical parameter of interest that characterizes the population for resolving decision statements (see Table 2-3).

Decision Statement No.	Abbreviated Decision Statement	Statistical Parameter of Interest
1	Determine whether the estimated VOC inventory remaining in the SDA pits and the current and future rate of release from the active 743-series drums will prevent the ultimate shutdown of the VVET system within the expected operational period.	Soil gas surveys—Mean or median (as appropriate) of the detected soil gas concentrations.
2, 3, 5, 6, 8	Determine whether the vadose zone vapor monitoring results obtained from the vapor plume meet the RGs for the respective locations indicated by the fate and transport model.	Favorable concentration trends[a] at each sample location over time (analyte concentrations versus time and Kendall's nonparametric trend test).
		The 95% UCL of the mean, lognormal mean, or median (as appropriate) vapor concentrations of all sampling locations within each RG zone.
2, 3	Determine whether the vadose zone vapor monitoring results obtained from the vapor plume during the short-term rebound periods meet the RGs for the respective locations indicated by the fate and transport model.	Favorable concentration "micro" trends[a] taken within each of the short-term rebound periods at selected sample locations (analyte concentrations versus time and Kendall's nonparametric trend test).
		Favorable concentration "macro" trend[a] analysis taken over 12 short-term rebound periods at selected sample locations (analyte concentrations versus time and Kendall's nonparametric trend test).
		The 95% UCL of the mean, lognormal mean, or median (as appropriate) vapor concentrations of selected sampling locations within each RG zone.
4	Determine whether the results predicted by the VOC fate and transport model using analytical data obtained during the short-term rebound periods from the combined Region A and B portions of the vapor plume indicate whether the groundwater MCLs will be met after the 100-year institutional period.	Detected values from each sample location in Regions A and B for model analysis.

Table 5-1. (continued).

Decision Statement No.	Abbreviated Decision Statement	Statistical Parameter of Interest
5, 6, 7	Determine whether the vadose zone vapor monitoring results obtained during the compliance verification phase meet the RGs.	Detected values from each sample location for model analysis.
	Determine whether the results predicted by the model using analytical data obtained during the compliance verification phase indicate whether the groundwater MCLs will be met after the 100-year institutional period.	
		Evaluation of analytical results on control charts. Exceeding upper control limits, or evidencing any of the sensitizing rules identified below, indicate unfavorable vapor conditions that may require renewal of system operations:
		One or more points outside the control limits
		A run of at least eight points where the type of run is limited to increasing values
		Two to three consecutive points outside the 2-sigma warning limits but still within the control limits
		Four or five consecutive points beyond the 1-sigma limits
		An unusual or nonrandom pattern in the data
		One or more points near a warning or control limit.
8, 9	Determine whether the vadose zone vapor monitoring results obtained during the long-term monitoring phase meet the RGs.	Detected values from each sample location for model analysis.
	Determine whether the results predicted by the model using analytical data obtained during the long-term monitoring phase indicate whether the groundwater MCLs will be met after the 100-year institutional period.	
		Evaluation of analytical results on control charts. Exceeding upper control limits, or meeting any of the sensitizing criteria identified below, indicates unfavorable vapor conditions that may require renewal of system operations:
		One or more points outside the control limits
		A run of at least eight points where the type of run is limited to increasing values
		Two to three consecutive points outside the 2-sigma warning limits but still within the control limits

Table 5-1. (continued).

Decision Statement No.	Abbreviated Decision Statement	Statistical Parameter of Interest
		Four or five consecutive points beyond the 1-sigma limits An unusual or nonrandom pattern in the data One or more points near a warning or control limit.

MCL = maximum contaminant level
RG = remediation goal
SDA = Subsurface Disposal Area
UCL = upper confidence limit
VOC = volatile organic compound
VVET = vapor vacuum extraction with treatment

a. A favorable concentration trend is defined as no trend (no change over time) or a decreasing concentration trend over time.
b. A systematic reduction of sampling frequency may be employed over time with favorable performance trends against the baseline.

Table 5-2. Scale of decision-making with enhanced temporal values for resolving decision statements (see Table 2-3).

Decision Statement No.	Population of Interest	Spatial Scale of Decision-Making	Temporal Scale of Decision-Making[a]
1	Shallow soil gas concentrations above VOC hot spots.	Shallow soils immediately around VOC hot spots at the west end of Pit 10 and the east end of Pit 4. Soil-gas sampling will be done using a regular grid above Pits 5 and 6 because a detailed soil gas survey has not been done over these pits. Soil-gas sampling may be performed above Pit 9 in the future.	As needed following completion of ARP waste retrieval activities. Begin with annual or biennial sampling over a several-year period.
2, 4, 5, 7, 8, 9	The portion of the VOC vapor plume (as indicated by CCl_4) that is within the influence or control of the current VVET system.	**Region A, RG Zone 1—**A reference boundary line that circumscribes certain vapor monitoring wells within the region of influence or control of the current VVET system from the ground surface to the 33.5-m (110-ft) B-C interbed. **Region A, RG Zone 2—**A border around vadose zone vapor monitoring wells that can sample from PRG Zone 2 (from the 33.5-m [110-ft] B-C depth to the 73-m [240-ft] C-D depth). **Region A, RG Zone 3—**A border around vadose zone vapor monitoring wells that extend into PRG Zone 3 (from below the 73-m [240-ft] C-D interbed).	Rolling 12-month periods based on monthly sampling throughout VVET operations (Decision Statements 2 through 4).

Table 5-2. (continued).

Decision Statement No.	Population of Interest	Spatial Scale of Decision-Making	Temporal Scale of Decision-Making[a]
			"Micro" trend analyses performed during individual short-term rebound periods (Decision Statements 2 and 3). "Macro" trend analyses performed over rolling 12 years of short-term rebound periods (Decision Statements 2 and 3). Rolling 12-month periods based on monthly sampling throughout compliance verification phase (Decision Statements 5 through 7). Rolling 12 semiannual[a] periods, based on semiannual[a] sampling throughout the long-term monitoring phase (Decision Statements 5 through 7).
4, 7, 8, 9, 10	The portion of the VOC vapor plume (as indicated by CCl_4) that is beyond the influence or control of the current VVET system.	**Region B, RG Zone 1—**A region that begins laterally at the Region A, Zone 1, spatial scale of decision-making boundary line out to a boundary described by the outermost OCVZ vapor monitoring wells. It extends vertically from the ground surface to the 33.5-m (110-ft) B-C interbed. **Region B, RG Zone 2—**A region that begins laterally at the Region A, Zone 2, spatial scale of decision-making boundary line to a boundary described by the outermost OCVZ vapor monitoring wells. The vertical boundary extends from the 33.5-m (110-ft) B-C interbed to the 73-m (240-ft) C-D interbed.	Rolling 12-month periods based on monthly sampling throughout VVET operations (Decision Statements 2 through 4).

Table 5-2. (continued).

Decision Statement No.	Population of Interest	Spatial Scale of Decision-Making	Temporal Scale of Decision-Making[a]
		Region B, RG Zone 3—A region that begins laterally at the Region A, Zone 3, spatial scale of decision-making boundary line to a boundary described by the outermost OCVZ vapor monitoring wells. This zone extends from below the 73-m (240-ft) C-D 240-ft interbed to groundwater.	"Micro" trend analyses performed during individual short-term rebound periods (Decision Statements 2 and 3).
			"Macro" trend analyses performed over rolling 12 years of short-term rebound periods (Decision Statements 2 and 3).
			Rolling 12-month periods based on monthly sampling throughout compliance verification phase (Decision Statements 5 through 7).
			Rolling 12 semiannual[a] periods based on semiannual[a] sampling throughout the long-term monitoring phase (Decision Statements 5 through 7).

COC = contaminant of concern
OCVZ = organic contamination in the vadose zone
RG = remediation goal
SDA = Subsurface Disposal Area
UCL = upper confidence limit
VOC = volatile organic compound
VVET = vapor vacuum extraction with treatment

a. Semiannual sampling during the long-term monitoring phase may shift to annual sampling after meeting control-chart limits for 3 consecutive years.

The results of previous soil gas surveys support process knowledge data related to the disposal locations of VOC-containing sludge. Shallow soil gas surveys will not be repeated unless additional disposal records are identified that indicate additional source areas may be present, or further source release rate determinations become necessary.

The action levels or preliminary action levels for each of the decision statements are specified in Table 5-3. The alternative actions are specified in Table 5-4.

Table 5-3. Action level for decision statements (see Table 2-3).

Decision Statement No.	Contaminants of Concern	Action Level
1	CCl_4, 1,1,1-trichloroethane, trichloroethene, and tetrachloroethene	Current and future rate of release from the active 743-series drums (TBD)[a].
2 through 9	CCl_4	Vapor concentration RGs in accordance with location (RG Zones 1–3). VOC concentrations below which VVET system operation is not cost-effective. Meeting groundwater MCLs after 100-year institutional period.

MCL = maximum contaminant level
RG = remediation goal
TBD = to be determined
VOC = volatile organic compound
VVET = vapor vacuum extraction with treatment

a. In this case, the rate of release is a relative rate of release, and changes can only be determined once a baseline has been established. The baseline will be established by the initial surveys.

Table 5-4. Alternative actions to resolve principal study questions (see Table 2-1).

Principal Study Question No.	No.	Alternative Action
1	1	The estimated VOC inventory remaining in the SDA pits and the current and future rate of release from the active 743-series drums may prevent the ultimate shutdown of the VVET system within the expected operational period. The OCVZ project decision-makers will consider treatment of removal of the SDA source material to protect groundwater from VOC contamination. ARP is planning to remove a significant portion of the original VOC inventory. This action will likely only apply to source areas not impacted by ARP.
1	2	The estimated VOC inventory remaining in the SDA pits and the current and future rate of release from the active 743-series drums may prevent the ultimate shutdown of the VVET system within the expected operational period. The OCVZ project decision-makers will consider adoption of more aggressive remedial action alternatives to protect groundwater from VOC contamination. This action will likely only apply to source areas not impacted by ARP.
1	3	The estimated VOC inventory remaining in the SDA pits and the current and future rate of release from the active 743-series drums may prevent the ultimate shutdown of the VVET system within the expected operational period. The OCVZ project and decision-makers will consider operating the VVET system over a longer operating period to ensure protection of groundwater from VOC contamination. This action will likely only apply to source areas not impacted by ARP.

Table 5-4. (continued).

Principal Study Question No.	No.	Alternative Action
1	4	The estimated VOC inventory remaining in the SDA pits and the current and future rate of release from the active 743-series drums are not projected to prevent the ultimate shutdown of the VVET system within the expected operational period. The OCVZ project and decision-makers determine that the VVET system may operate as planned until the requirements have been met for shutdown of the VVET system.
1	5	No action.
2	1	The vadose zone vapor monitoring results obtained during VVET system operations from each of the zones in the Region A vapor plume meet the RGs for the respective locations indicated by the fate and transport model. Evaluate PSQ 3.
2	2	The vadose zone vapor monitoring results obtained during VVET system operations from each of the zones in the Region A vapor plume reach VOC concentrations below which VVET operations are no longer cost effective. The OCVZ project and decision-makers evaluate changes to the VVET system operating cycles. Evaluate PSQ 3.
2	3	The vadose zone vapor monitoring results obtained during VVET system operations from each of the zones in the Region A vapor plume do not meet the RGs for the respective locations indicated by the fate and transport model. The RAOs will not be satisfied, and VVET system operation must continue.
2	4	No action.
3	1	The vadose zone vapor monitoring results obtained from each of the zones in the Region B vapor plume meet the RGs for the respective locations indicated by the fate and transport model during VVET system operations. Evaluate PSQ 4.
4	2	The vadose zone vapor monitoring results obtained from each of the zones in the Region B vapor plume do not meet the RGs for the respective locations indicated by the fate and transport model during VVET system operations. The RAOs will not be satisfied. The OCVZ project and decision-makers evaluate the expansion of the VVET system into Region B.
3	3	No action.
4	1	The results predicted by the VOC fate and transport model using analytical data obtained during VVET system operations from the combined Region A and B portions of the vapor plume indicate that the groundwater MCLs will be met after the 100-year institutional period. The RAOs have been satisfied. The VVET system will be evaluated for shutdown and start of the compliance verification phase.

Table 5-4. (continued).

Principal Study Question No.	No.	Alternative Action
4	2	The results predicted by the VOC fate and transport model using analytical data obtained during VVET system operations from the combined Region A and B portions of the vapor plume indicate that the groundwater MCLs will not be met after the 100-year institutional period. The RAOs are not satisfied. The OCVZ project and decision-makers may evaluate continued operation of the current system or expansion of the VVET system.
4	3	No action.
5	1	The vadose zone vapor monitoring results obtained from each of the zones within the Region A portion of the vapor plume during the compliance verification phase meet the RGs for the respective locations indicated by the fate and transport model. Evaluate PSQ 6.
5	2	The vadose zone vapor monitoring results obtained from each of the zones within the Region A portion of the vapor plume during the compliance verification phase do not meet the RGs for the respective locations indicated by the fate and transport model. The RAOs will not be satisfied. The OCVZ project and decision-makers evaluate the resumption of VVET system operations.
5	3	No action.
6	1	The vadose zone vapor monitoring results obtained from each of the zones within the Region B portion of the vapor plume during the compliance verification phase meet the RGs for the respective locations indicated by the fate and transport model. Evaluate PSQ 7.
6	2	The vadose zone vapor monitoring results obtained from each of the zones within the Region B portion of the vapor plume during the compliance verification phase do not meet the RGs for the respective locations indicated by the fate and transport model. The RAOs will not be satisfied. The OCVZ project and decision-makers evaluate the expansion of the VVET system into Region B.
6	3	No action.
7	1	The results predicted by the VOC fate and transport model using analytical data obtained during the compliance verification phase from the combined Region A and B portions of the vapor plume indicate that the groundwater MCLs will be met after the 100-year institutional period. The RAOs have been satisfied. The OCVZ project and decision-makers will evaluate the start of the long-term monitoring phase.

Table 5-4. (continued).

Principal Study Question No.	No.	Alternative Action
7	2	The results predicted by the VOC fate and transport model using analytical data obtained during the compliance verification phase from the combined Region A and B portions of the vapor plume indicate that the groundwater MCLs will not be met after the 100-year institutional period. The RAOs will not be satisfied. The OCVZ project and decision-makers evaluate the restart and expansion alternatives for the VVET system in both Regions A and B.
7	3	No action.
8	1	The vadose zone vapor monitoring results obtained from each of the zones within the Region A and B portions of the vapor plume during the long-term monitoring phase meet the RGs for the respective locations indicated by the fate and transport model. Evaluate PSQ 9.
8	2	The vadose zone vapor monitoring results obtained from each of the zones within the Region A and B portions of the vapor plume during the long-term monitoring phase do not meet the RGs for the respective locations indicated by the fate and transport model. The RAOs will not be satisfied. Evaluate PSQ 9. The project and decision-makers evaluate the restart and expansion alternatives for the VVET system in both Regions A and B.
8	3	No action.
9	1	The results predicted by the VOC fate and transport model using analytical data obtained during the long-term monitoring phase from the combined Region A and B portions of the vapor plume indicate that the groundwater MCLs will be met after the 100-year institutional period. The RAOs have been satisfied. The OCVZ project and decision-makers determine that the long-term monitoring phase should continue.
9	2	The results predicted by the VOC fate and transport model using analytical data obtained during the long-term monitoring phase from the combined Region A and B portions of the vapor plume indicate that the groundwater MCLs will not be met after the 100-year institutional period. The RAOs will not be satisfied. The OCVZ project and decision-makers evaluate the restart and expansion alternatives for the VVET system in both Regions A and B.
9	3	No action.

MCL = maximum contaminant level
OCVZ = organic contamination in the vadose zone
PSQ = principal study question
RG = remediation goal
SDA = Subsurface Disposal Area
VOC = volatile organic compound
VVET = vapor vacuum extraction with treatment

5.2 Decision Rules

The output of DQO Step 5 and the previous DQO steps are combined into "IF...THEN" decision rules that incorporate the parameter of interest, the scale of decision-making, the action level, and the actions that would result from resolution of the decision. The decision rules are presented in Table 5-5.

Table 5-5. Decision Rules.

No.	Decision Rule
1a	If the estimated VOC inventory remaining in the SDA pits and the current and future rate of release from the active 743-series drums may prevent the ultimate shutdown of the VVET system within the expected operational period, then the project decision-makers will evaluate three alternative actions: • Treatment or removal of the SDA source material to protect groundwater from VOC contamination • Adoption of more aggressive remedial action alternatives to protect groundwater from VOC contamination • Operating the VVET system over a longer period to protect groundwater from VOC contamination.
1b	If the estimated VOC inventory remaining in the SDA pits and the current and future rate of release from the active 743-series drums is not projected to prevent the ultimate shutdown of the VVET system within the expected operational period, then the OCVZ project and decision-makers will evaluate operation of the VVET system as planned until the shutdown requirements are satisfied.
2	If the vapor monitoring analytical results obtained during VVET system operations from all PRG zones for both Regions A and Region B of the vapor plume show that all of the following requirements have been met: • The analytical results show favorable vapor concentration trends over 12 months of VVET operations for individual sampling locations • The 95% UCL of the mean, lognormal mean, or median (as appropriate) vapor concentrations of all sampling locations within each RG zone do not exceed the respective RGs,[a] then evaluate Decision Rule 3 for satisfaction of the RAOs and possible suspension of the VVET system operations. If the vapor monitoring analytical results for this decision rule do not meet all the requirements described above, then the OCVZ project and decision-makers will evaluate the alternatives presented in Figures 5-1 and 5-2.

Table 5-5. (continued).

No.	Decision Rule
3a	If Decision Rule 2 has been satisfied, and the vapor monitoring analytical results obtained during the short-term vadose zone rebound periods from within all RG zones for Regions A and B of the vapor plume show that the following requirements have been met in less than 12 years: • The analytical results show favorable vapor concentration trends within each of the short-term rebound periods for individual sampling locations • The 95% UCL of the mean, lognormal mean, or median (as appropriate) vapor concentrations of the specified sampled locations within each RG zone are significantly below the respective RGs[a] • Continued operation of the current VVET system clearly would not be cost effective, then the OCVZ project and decision-makers may evaluate Decision Rule 4 for satisfaction of the RAOs and possible suspension of the VVET system operations or modification of the operating cycles. If the vapor monitoring analytical results for this decision rule do not meet the requirements described above, then the OCVZ project and decision-makers will evaluate the alternatives presented in Figure 5-3.
3b	If Decision Rule 2 has been satisfied, and the vapor monitoring analytical results obtained during the short-term vadose zone rebound periods from within all RG zones for Regions A and B of the vapor plume show that the following requirements have been met: • The analytical results show favorable vapor concentration trends within each of the short-term rebound periods for individual sampling locations • The 95% UCL of the mean, lognormal mean, or median (as appropriate) vapor concentrations of the specified sampled locations within each RG zone do not exceed the respective RGs[a] • The analytical results show favorable vapor concentration trends over a 12-year rolling period of monitoring the short-term rebound periods at individual sampling locations, then the OCVZ project and decision-makers may evaluate Decision Rule 4 for satisfaction of the RAOs and possible suspension of the VVET system operations. If the vapor monitoring analytical results for this decision rule do not meet the requirements described above, then the OCVZ project and decision-makers will evaluate the alternatives presented in Figure 5-3.
4	If the results predicted by the VOC fate and transport model using detected vapor concentrations obtained during the short-term rebound periods from the combined Region A and B portions of the vapor plume indicate that the groundwater MCLs will be met at the compliance point after the 100-year institutional period, then the decision-makers will evaluate the shutdown of the VVET system and start of the compliance verification phase. If the vapor monitoring analytical results for this decision rule do not meet the requirements described above, then the OCVZ project and decision-makers will evaluate the alternatives presented in Figure 5-3.

Table 5-5. (continued).

No.	Decision Rule
5	If the vapor monitoring analytical results obtained during the compliance verification phase from within all RG zones for both the Region A and Region B of the vapor plume meet all of the following requirements: • The analytical results predicted by the VOC fate and transport model indicate that the groundwater MCLs will be met at the compliance point after the 100-year institutional period • The analyses are favorable via control charts as depicted in Table 5-1, then, the RAOs have been satisfied. The OCVZ project and decision-makers may evaluate the start of the long-term monitoring period. If the vapor monitoring analytical results for this decision rule do not meet the requirements described above, then the project and decision-makers will evaluate the alternatives presented in Figure 5-4.
6	If the vapor monitoring analytical results obtained during the long-term monitoring phase from within all RG zones for both Region A and Region B of the vapor plume meet all of the following requirements: • The results predicted by the VOC fate and transport model indicate that the groundwater MCLs will be met at the compliance point after the 100-year institutional period • The analyses are favorable via control charts as depicted in Table 5-1, then, the RAOs have been satisfied. The project and decision-makers may evaluate continuation of the long-term monitoring period. If the vapor monitoring analytical results for this decision rule do not meet the requirements described above, then the OCVZ project and decision-makers will evaluate the restart and expansion alternatives for the VVET system for Regions A and B. See Figure 5-5.

MCL = maximum contaminant level
OCVZ = organic contamination in the vadose zone
PSQ = principal study question
RG = remediation goal
SDA = Subsurface Disposal Area
VOC = volatile organic compound
VVET = vapor vacuum extraction with treatment

a. Preliminary RGs are to be determined and are location specific (Preliminary Remedial Goal Zones 1, 2, or 3) as developed by the fate and transport model.
b. The model will evaluate compliance for all four of the primary contaminants of concern in accordance with footnote b in Table 1-4.

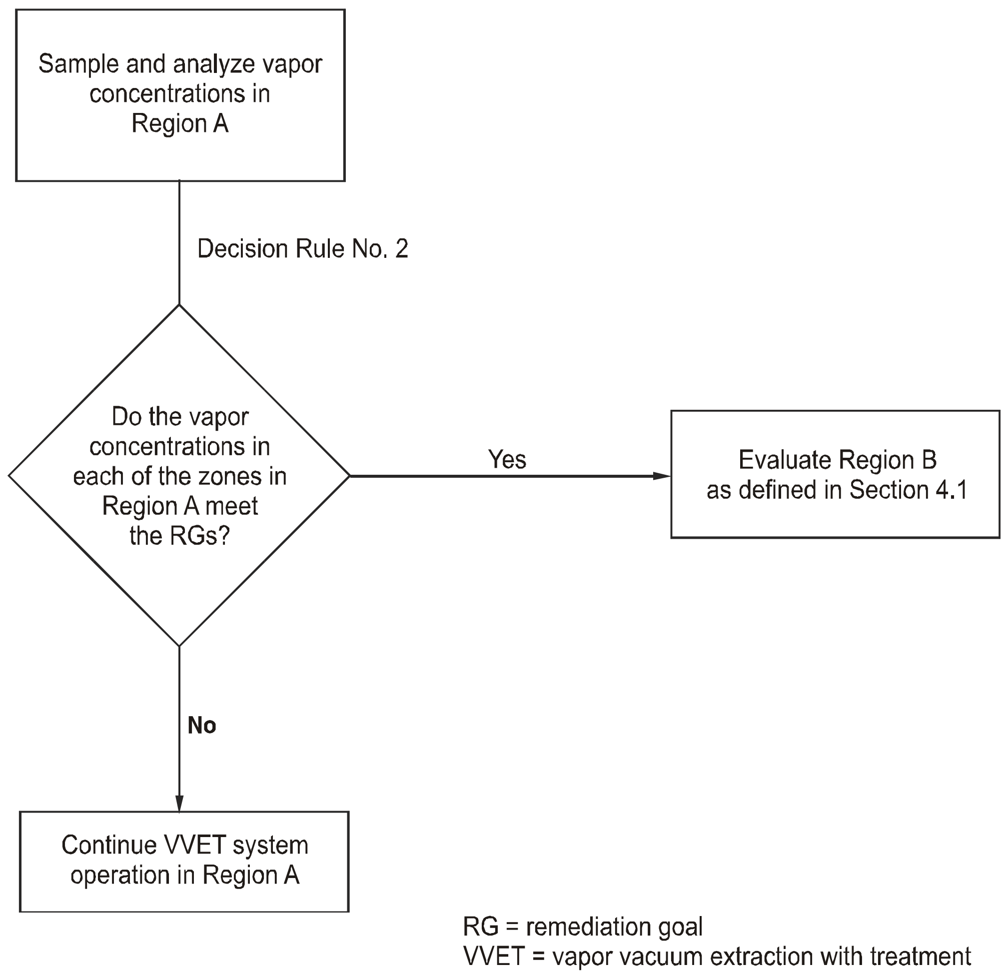


Figure 5-1. Decision Rule 2 decision-making logic flow diagram for Region A.

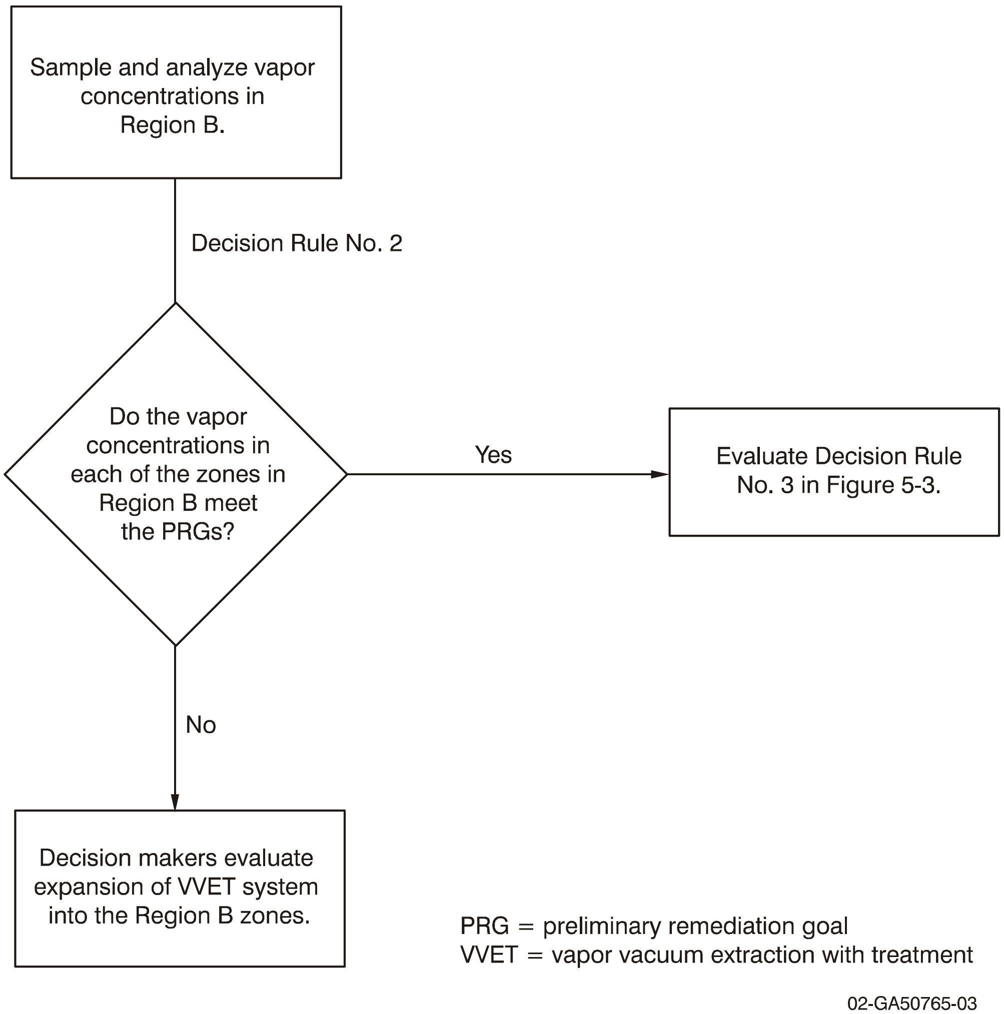


Figure 5-2. Decision Rule 2 decision-making logic flow diagram for Region B.

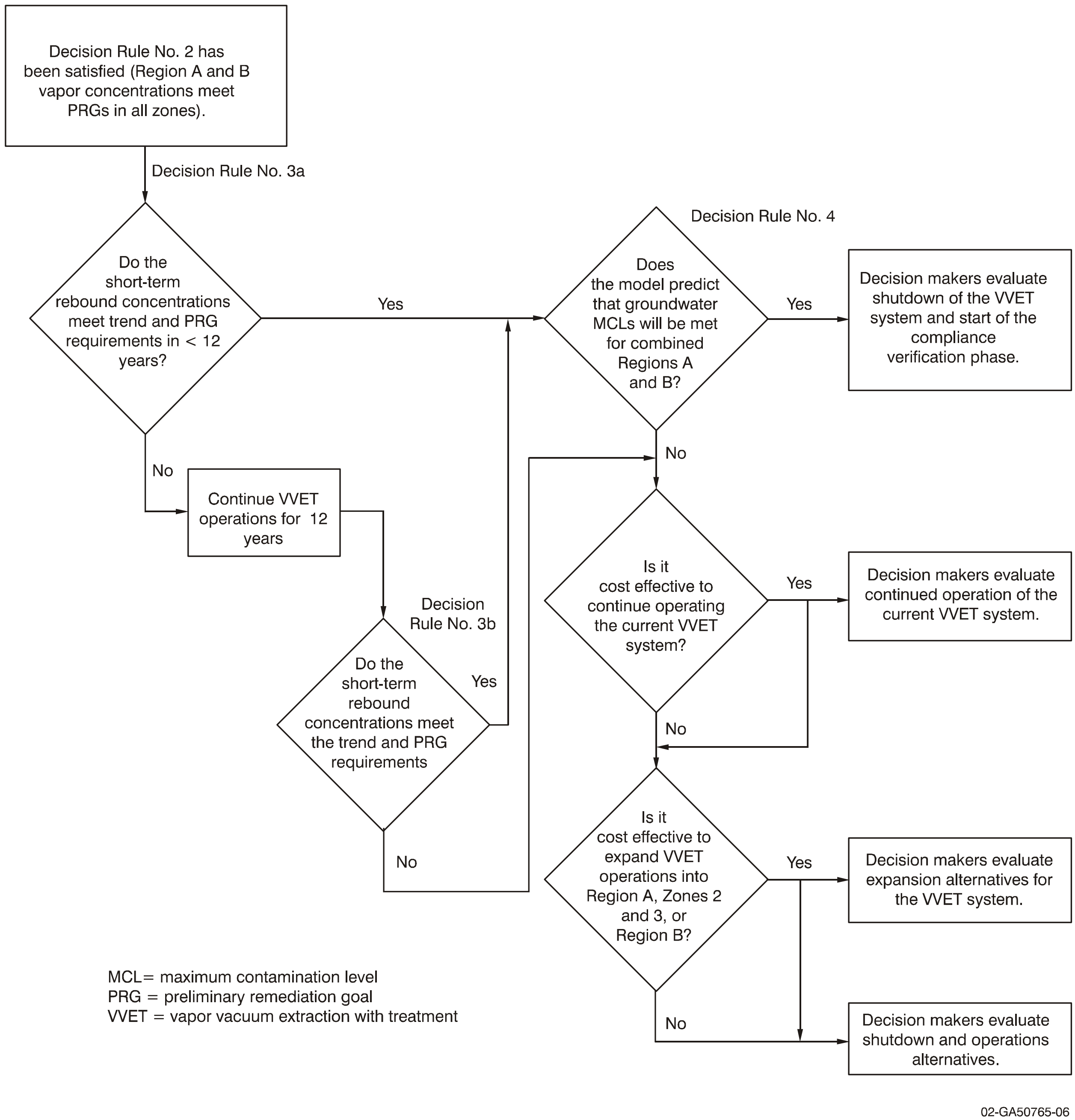


Figure 5-3. Decision Rules 3 and 4 decision-making logic flow diagram.

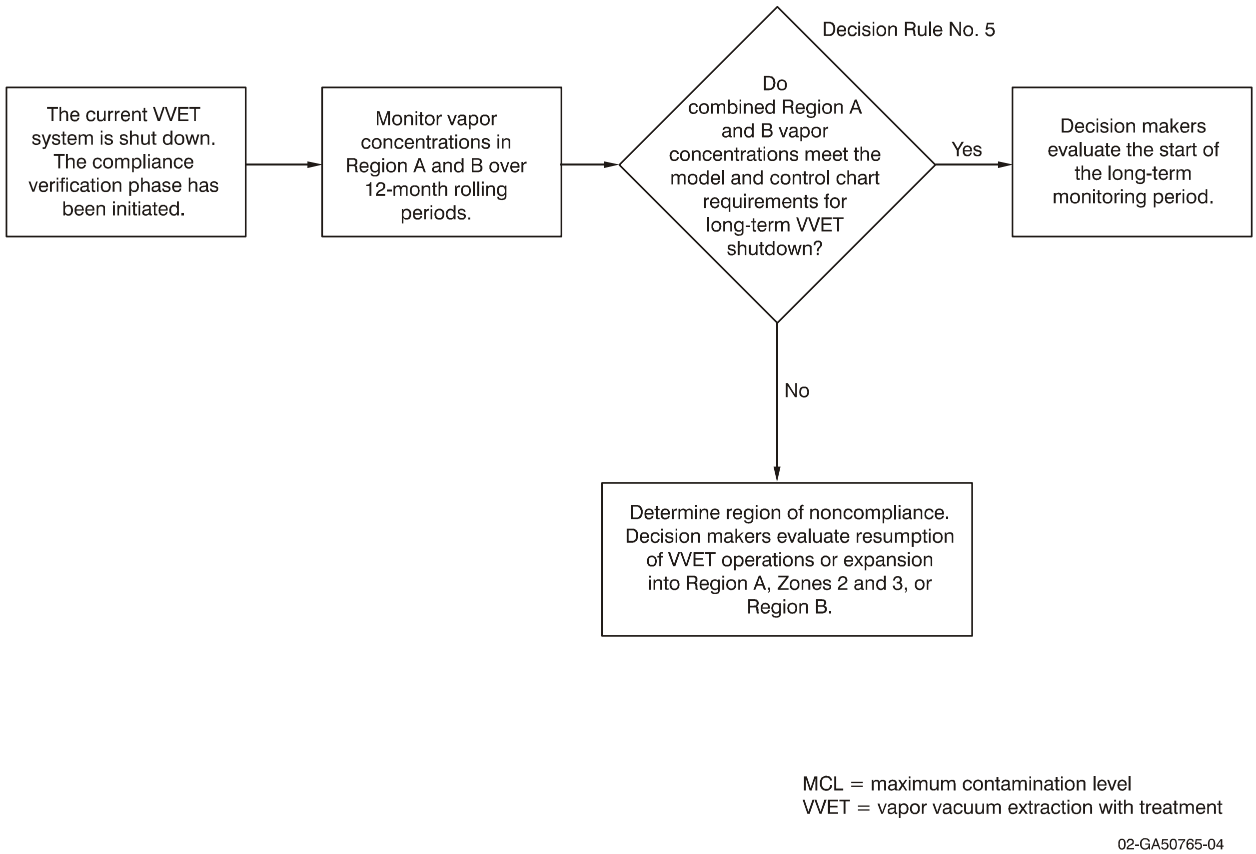


Figure 5-4. Decision Rule 5 decision-making logic flow diagram for the compliance verification phase.

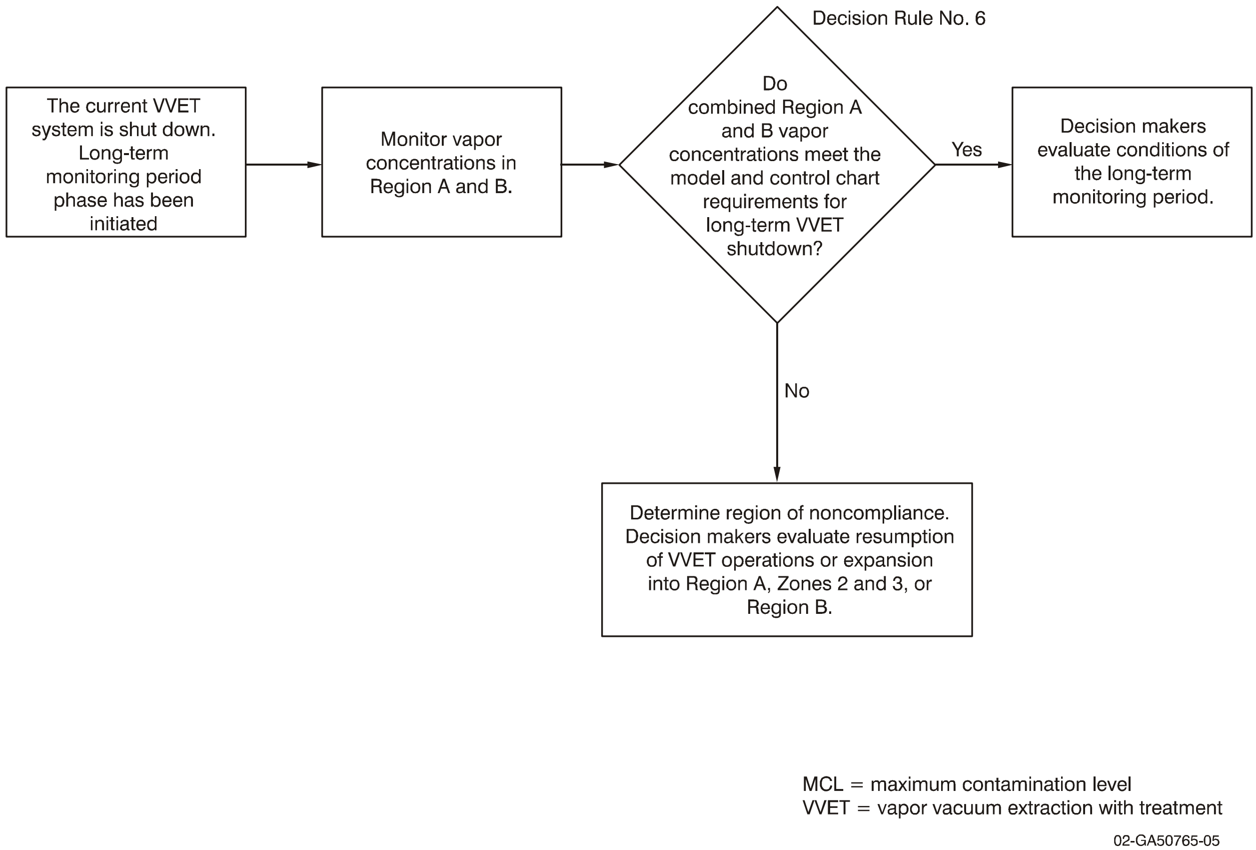


Figure 5-5. Decision Rule 6 decision-making logic flow diagram for the long-term monitoring period.

5.2.1 Notes on Decision Rules 3a and 3b

Decision Rules 3a and 3b allow for two different conditions to satisfy the short-term rebound period shutdown requirements. Because they are mutually exclusive, only 3a or 3b may be employed to bring the shutdown assessment to Decision Rule 4.

Decision Rule 3a recognizes the potential for the VVET system to bring the Zone A1 vapor concentrations well below the RGs or to the point of cost-ineffectiveness in less than the 12 years required to satisfy the "macro" trend requirements (see Table 5-1 for Decision Statements 2, 3, and 4). Under these conditions, fulfilling 12 years of short-term rebound trending is unnecessary.

Decision Rule 3b is the base case that requires a rolling trend of 12 years of satisfactory short-term rebound response to support system shutdown. The logic that shows the relationship between these decision rules is provided in Figure 5-3.

6. STEP 6—SPECIFY TOLERABLE LIMITS ON DECISION ERRORS

Because analytical data can estimate only the true condition of the site under investigation, decisions based on measurement data potentially could be in error (i.e., decision error). For this reason, the primary objective of DQO Step 6 is to define the tolerable limits on the probability of making a decision error.

Tolerable error limits assist in the development of sampling designs to ensure that the spatial variability and sampling frequency are within specified limits. However, the sampling design for OCVZ is determined by locations of the current monitoring wells and available locations for installation of new wells in and around the SDA boundary. New monitoring well locations will be based on professional judgment using the available data and after consensus by the OCVZ project and decision-makers. Consequently, Step 6 will not be used to establish tolerable decision errors in this DQO.

7. STEP 7—OPTIMIZE THE DECISION

7.1 Purpose

The intent of DQO Step 7 is to identify the most resource-effective design for generating data to support decision-making while maintaining the desired degree of precision and accuracy. When determining an optimal design, the following actions should be performed:

- Identify potential screening method alternative
- Identify general data collection design alternative
- Select the most resource-effective data collection design that satisfies the project goals
- Document the operational details and theoretical assumptions of the selected design.

7.2 Potential Screening Method Alternatives

The potential screening technologies that were considered to resolve each decision statement and the optional method of implementing each technology are identified in Table 7-1. The limitations associated with each screening technology or method of implementation and relative cost for implementation is also summarized in this table.

7.3 Potential Sampling Design Alternatives

The various types of media that need to be sampled to resolve each decision statement and alternative methods for collecting these samples are identified in Table 7-2. Alternative implementation designs for each sampling method are presented in the table, and any limitations associated with each sampling method or design are identified.

7.4 Implementation Design

All selected screening technologies and sampling methods for resolving each decision statement, along with a summary of the proposed implementation design, are presented in Table 7-3. The table also provides the basis for the selected implementation design. A summary of ongoing and planned sampling for OU 7-08 is provided in Table 7-4.

7.4.1 Soil Gas Surveys

Shallow soil gas measurements have been performed over the three primary areas known to contain the largest amounts of VOCs. Shipping and disposal records indicate that nearly all VOC sludge was buried in these locations. Soil gas surveys of the SDA performed during 1987 and 1992 and the subsequent focused soil gas survey of Pits 4, 5, and 10 corroborated the process-knowledge-indicated locations (Housley, Sondrup, and Varvel 2002).

Soil gas surveys are performed by installing monitoring tubes into the shallow sedimentary soils immediately adjacent to the SDA buried waste in known hot spot areas. The soil gases are swept up into the monitoring tubes and analyzed by an online VOC detector. Alternatively, soil gases may be collected in a container for on-Site or off-Site laboratory analysis.

Table 7-1. Potential screening alternative when applying decision rules (see Table 5-5).

Decision Rule No.	Media	Screening Technology	Potential Implementation Designs	Potential Limitations	Cost
1	Shallow soils	Soil gas surveys	Sample soil gas with in situ sampling system	Spatial, temporal variability, instrument sensitivity, and gas tube seals	Low
2 through 6	Vapor analysis for CCl_4, 1,1,1-trichloroethane, trichloroethene, and tetrachloroethene	Photoacoustic analyzer	Collect vapor samples for analysis in on-Site screening laboratory	May lack quality assurance and quality control capabilities	Medium
2 through 6	Groundwater analysis	Portable GC	Must be purchased	Other contaminants may interfere. May lack quality assurance and quality control capabilities	Medium
		Headspace volatilization photoacoustic analyzer	Must be purchased	Other contaminants may interfere. May lack quality assurance and quality control capabilities	Medium

Table 7-2. Potential sampling design alternatives.

Sampling Alternative No.	Sample Collection Methodology	Key Features of Design	Basis for Sampling Design	Potential Disadvantages	Discussion
Subsurface Disposal Area Remaining Volatile Organic Compounds Inventory Determination					
RV1	Monitor soil gas.	In situ soil-gas monitoring of areas adjacent to and above buried waste.	Low-cost field screening and on-Site laboratory technique.	Laboratory quality assurance/quality control is lacking. Spatial, temporal variability, instrument, and tube seal sensitivity.	Methodology is used to determine trends in VOC release rate. Samples also may be sent to on-Site laboratory.
Vadose Zone Vapor Monitoring					
V1	Use present vapor monitoring wells in and around the SDA.	Shallow samples collected from existing and new sampling wells in SDA. Use wells outside the SDA to fill gaps in spatial distribution. Collect deep samples from the new wells in the SDA and from SDA perimeter wells.	Practicality: reliance on existing wells for vapor data.	None.	Existing vapor monitoring wells provide reasonably good spatial distribution.
V2	Install new vapor wells within the SDA.	New vapor wells to augment existing well configuration for enhanced plume mapping.	Filling of data gaps in spatial distribution.	Restrictions are imposed on access to locations for well drilling; cost.	Addition of new well locations in the SDA enhances the spatial distribution.
V3	Angle drill.	New vapor monitoring wells in the SDA by angle drilling from outside the SDA boundary.	Access restrictions are overcome by drilling wells from outside the SDA.	Placement of well may not be as accurate as vertical drilling. Cost may be high.	Angle drilling may overcome surface access concerns. Contaminant transport and cost concerns.

Table 7-2. (continued).

Sampling Alternative No.	Sample Collection Methodology	Key Features of Design	Basis for Sampling Design	Potential Disadvantages	Discussion
V4	Monitor gases from the VVET unit influent piping.	Samples collected from VVET treatment influent gas for on-Site screening laboratory analysis.	Information can be obtained without addition of new wells.	Data obtained can support mass removal estimates, but may not be directly comparable to well monitoring data.	This sampling practice can provide supplemental total VOC mass removal information to the project at low cost.
Groundwater Monitoring					
GW1	Groundwater monitoring within the SDA.	Groundwater monitoring limited to the existing well.	Practicality: methodology makes use of existing wells and avoids expense and potential for cross-contamination of vadose zone and groundwater by well-drilling activities.	Only one groundwater well in the SDA.	No spatial distribution of groundwater data within the SDA with one well.
GW2	Groundwater monitoring with existing wells around the perimeter of the SDA.	Groundwater monitoring limited to the existing wells.	Practicality: methodology makes use of existing wells and avoids expense and potential for cross-contamination of vadose zone and groundwater by well-drilling activities.	South perimeter wells have low permeability and do not reflect VOC concentration changes with other wells.[a]	Other groundwater wells may be needed to fill the data gaps. Low-permeability wells have limited usefulness.[a]
GW3	Groundwater monitoring distant from the SDA boundary.	Groundwater monitoring limited to the existing wells.	Practicality: methodology makes use of existing wells.	Spatial distribution of wells distant from the SDA is incomplete.	Additional wells are needed for areal coverage and to fill data gaps created by the low permeability wells.[a]

Table 7-2. (continued).

Sampling Alternative No.	Sample Collection Methodology	Key Features of Design	Basis for Sampling Design	Potential Disadvantages	Discussion
GW4	New groundwater monitoring wells.	New groundwater wells around the SDA for spatial distribution. New groundwater wells distant from the SDA for spatial distribution.	New groundwater wells would support further refinements of the model.	Cost may be high, access may be limited; should avoid the low-permeability zones. [a]	New groundwater wells would fill data gaps. Cost, access limitations, and low permeability areas should be considered when placing new wells. [a]

a. Low permeability zone defined by wells: USGS-88, USGS-89, USGS-117, USGS-119, M1S, M4D, M6S, and M10S.

SDA = Subsurface Disposal Area
VOC = volatile organic compound
VVET = vapor vacuum extraction with treatment

Table 7-3. Most resource-effective data collection design.

Sampling Alternative No.	Sample Collection Methodology	Key Features of Design	Basis for Sampling Design
Subsurface Disposal Area Remaining Volatile Organic Compound Inventory Determination			
RV1	Soil-gas monitoring.	In situ soil-gas monitoring adjacent to and above SDA buried waste. Historical soil gas data and disposal records (see Figure 1-6) are used to focus sampling.	Field screening technique is low-cost, and laboratory technique is on-Site.
Vadose Zone Vapor Monitoring			
V1	Use present vapor monitoring wells in and around the SDA.	Sampling of existing vapor sampling wells within the SDA during VVET operations and during compliance verification periods. Use of wells located around the perimeter of SDA to fill the gap in the spatial distribution. Sample monthly for trend analyses. Use of on-Site laboratory while unfavorable trends or concentrations are detected when compared with RGs. Shift to off-Site labs when trending or concentrations become favorable. (Note: A 12-month favorable trend is required for the shutdown decision.) (A plan view of the SDA with shallow, intermediate, and deep vadose zone vapor monitoring well locations is shown in Figures 7-1 through 7-3.)	Practicality: use of existing wells for vapor data is maximized.
V4	Monitor gases from the VVET unit extraction inlet line.	Samples collected from VVET Units D, E and F from the influent gas for on-Site screening lab analysis. Sampling frequency is TBD by the project.	Provides supplemental total VOC mass removal information to the project at low cost.

Table 7-3. (continued).

Sampling Alternative No.	Sample Collection Methodology	Key Features of Design	Basis for Sampling Design
Groundwater Monitoring			
GW1 GW2 GW3	Groundwater monitoring in and around the SDA perimeter and distant from SDA boundary.	Sampling of groundwater in existing wells within and around the SDA perimeter, and distant from the SDA during VVET operations, and during compliance verification periods. Sampling on quarterly basis for trend analyses. Use of on-Site lab for groundwater monitoring. Groundwater well locations in and around the SDA are shown in Figure 7-4.	Practicality: Use of existing wells is maximized.

RG = remediation goal
SDA = Subsurface Disposal Area
TBD = to be determined
VOC = volatile organic compound
VVET = vapor vacuum extraction with treatment

Table 7-4. Organic contamination in the vadose zone sampling summary.

Sampling Activity	Sample Location Designation[a]	Sampling Frequency	Reference Figure
SDA soil-gas monitoring	Soil gas sampling locations will be determined after ARP activities are complete. Sampling will be conducted on regular grids over source areas not impacted by ARP. ARP impacted areas may be sampled to confirm minimal releases.	As needed	Not available
PRG Zone 1 (shallow) vapor monitoring (VVET operations and compliance verification phases)	Region A: 2E, 3E, 4E, 5E, 3V, 4V, 5V, 6V, 7V, 8V, **IE3**, **IE4**, **IE6**, **IE7**, **IE8**, DO2, 8801, 8902, 9301, 9302.	Monthly	Figure 7-1
	Region B: 1E, 1V, 2V, 9V, 10V, **1898**, **RWMC-2004**, 77-1, 78-4, USGS-118, VVE-1, VVE-3, VVE-10.		
	Region B: WWW-1, VVE-4, VVE-6, VVE-7, OCVZ-11, OCVZ-13, OCVZ-14, M15S, M16S.	Quarterly	
	VVET unit influent piping from Units D, E, and F during VVET operations.	TBD by the project	Not available
PRG Zone 2 (intermediate) vapor monitoring (VVET operations and compliance verification phases)	Region A: 3E, 3V, 4V, 5V, 6V, 7V, 8V, **DE3, DE4**, **DE6**, **DE7**, **DE8**, DO2, 8801, 8902, 9301, 9302.	Monthly	Figure 7-2
	Region B: 2V, 9V, 10V, **1898**, **RWMC-2004**, 77-1, USGS-118, VVE-1, VVE-3, VVE-10.		
	Region B: WWW-1, VVE4, VVE-6, VVE-7, OCVZ-13, OCVZ-14, M15S, M16S.	Quarterly	
PRG Zone 3 (deep) vapor monitoring (VVET operations and compliance verification phases)	Region A: DE1, **DE3**, **DE4**, **DE6**, **DE7**, **DE8**, M17S.	Monthly	Figure 7-3
	Region B: **1898**, 78-4, USGS-118, M1S, M3S, M10S, **M10SR (1835)**.		
	Region B: WWW-1, M4D, M6S, M7S, M11S, OCZV-13, M13S, OCVZ-14, M14S, M15S, M16S.	Quarterly	
PRG Zone 1 (shallow) vapor monitoring (short-term rebound periods)	Region A: 2E, 3E, 4E, 5E, 3V, 4V, 5V, 6V, 7V, 8V, **IE3**, **IE4**, **IE6**, **IE7**, **IE8**, DO2, 8801, 8902, 9301, 9302.	12 sampling events per short-term rebound period	Figure 7-1
	Region B: 1E, 1V, 2V, 9V, 10V, **1898**, **RWMC-2004**, 77-1, 78-4, USGS-118, VVE-1, VVE-3, VVE-10.		
PRG Zone 2 (intermediate) vapor monitoring (short-term rebound periods)	Region A: 3E, 3V, 4V, 5V, 6V, 7V, 8V, **DE3**, **DE4**, **DE6**, **DE7**, **DE8**, DO2, 8801, 8902, 9301, 9302.	12 sampling events per short-term rebound period	Figure 7-2
	Region B: 2V, 9V, 10V, **1898**, **RWMC-2004**, 77-1, USGS-118, VVE-1, VVE-3, VVE-10.		

Table 7-4. (continued).

Sampling Activity	Sample Location Designation[a]	Sampling Frequency	Reference Figure
PRG Zone 3 (deep) vapor monitoring (short-term rebound periods)	Region A: DE1, **DE3**, **DE4**, **DE6**, **DE7**, **DE8**, M17S. Region B: **1898**, 78-4, USGS-118, M1S, M3S, M10S, **M10SR (1835)**.	12 sampling events per short-term rebound period	Figure 7-3
Groundwater monitoring (VVET operations and compliance verification phases)	Region A: M17S. Region B: RWMC, USGS-87, USGS-88, USGS-89, USGS-90, USGS-117, USGS-119, USGS-120, USGS-127, M1S, M3S, M4D, M6S, M7S, M11S, M13S, M14S, M15S, M16S, EBR-1, A11A31, OW-2.	Quarterly	Figure 7-4
PRG Zone 1 (shallow) vapor monitoring (long-term monitoring phase)	Region A: 2E, 3E, 4E, 5E, 3V, 4V, 5V, 6V, 7V, 8V, **IE3**, **IE4**, **IE6**, **IE7**, **IE8**, DO2, 8801, 8902, 9301, 9302. Region B: 1E, 1V, 2V, 9V, 10V, **1898**, **RWMC-2004**, 77-1, 78-4, USGS-118, VVE-1, VVE-3, VVE-4, VVE-10.	Semiannually /annually[b]	Figure 7-1
	Region B: WWW-1, VVE-6, VVE-7, OCVZ-11, OCVZ-13, OCVZ-14, M15S, M16S.	Annually/ biennially	
PRG Zone 2 (intermediate) vapor monitoring (long-term monitoring phase)	Region A: 3E, 3V, 4V, 5V, 6V, 7V, 8V, **DE3**, **DE4**, **DE6**, **DE7**, **DE8**, DO2, 8801, 8902, 9301, 9302. Region B: 2V, 9V, 10V, **1898**, **RWMC-2004**, 77-1, USGS-118, VVE-1, VVE-3, VVE-10.	Semiannually /annually[b]	Figure 7-2
PRG Zone 3 (deep) vapor monitoring (long-term monitoring phase)	Region A: 3E, 3V, 4V, 5V, 6V, 7V, 8V, **DE3**, **DE4**, **DE6**, **DE7**, **DE8**, DO2, 8801, 8902, 9301, 9302. Region B: 2V, 9V, 10V, **1898**, **RWMC-2004**, 77-1, USGS-118, VVE-1, VVE-3, VVE-10.	Semiannually /annually[b]	Figure 7-3
Groundwater monitoring (long-term monitoring phase)	Region A: M17S. Region B: RWMC, USGS-87, USGS-88, USGS-89, USGS-90, USGS-117, USGS-119, USGS-120, USGS-127, M1S, M3S, M4D, M6S, M7S, M11S, M13S, M14S, M15S, M16S, EBR-1, A11A31, OW-2.	Annually/ biennially	Figure 7-4

RG = remediation goal
SDA = Subsurface Disposal Area
TBD = to be determined
VOC = volatile organic compound
VVET = vapor vacuum extraction with treatment

a. **Bold font** indicates a new well that was constructed since revision 1 of the DQO was issued.

b. If semiannual sampling results fall within the control limits defined for all locations for three successive years, sampling frequency will be reduced to a single annual event per location.

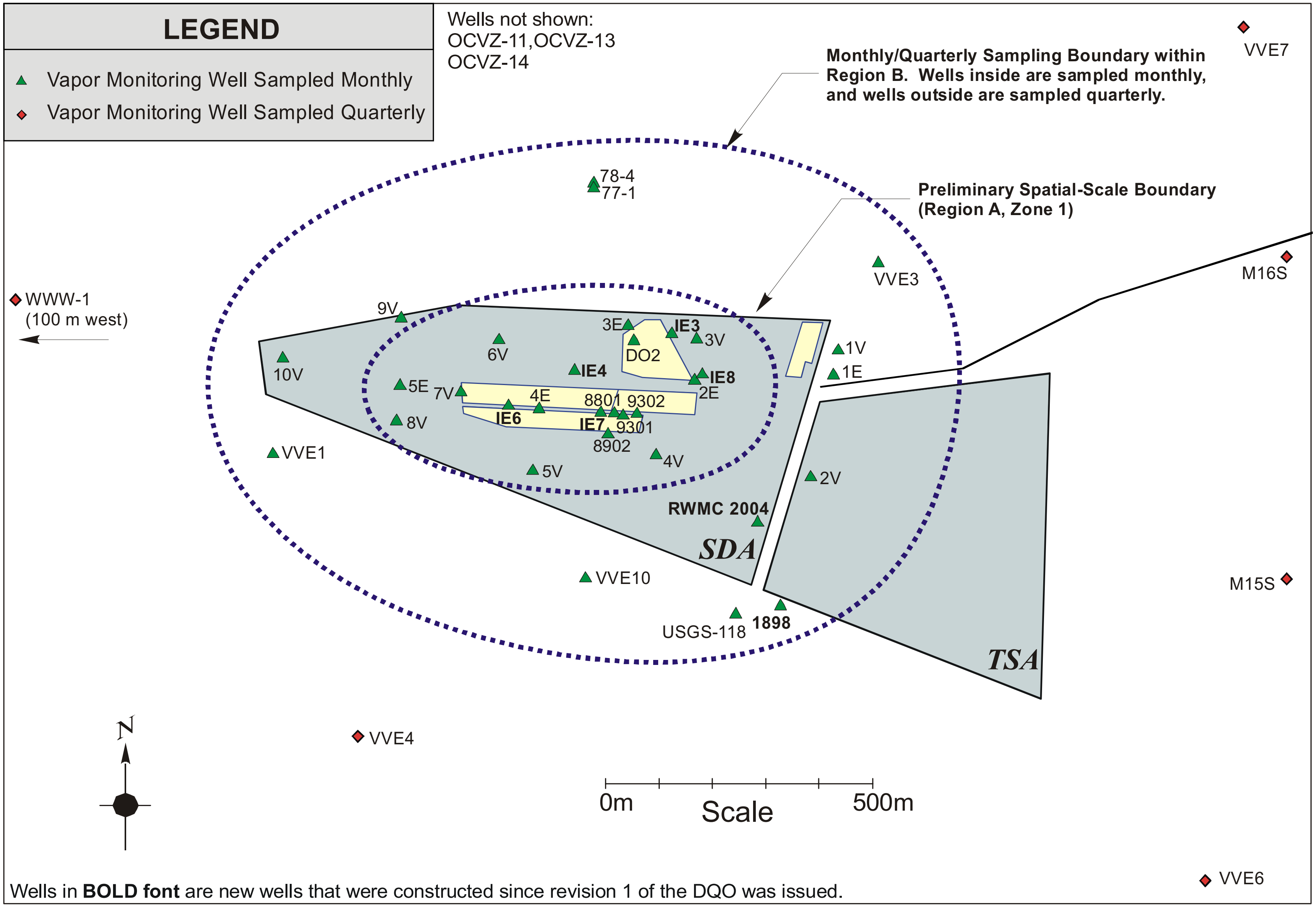


Figure 7-1. Organic contamination in the vadose zone shallow vadose zone vapor monitoring wells.

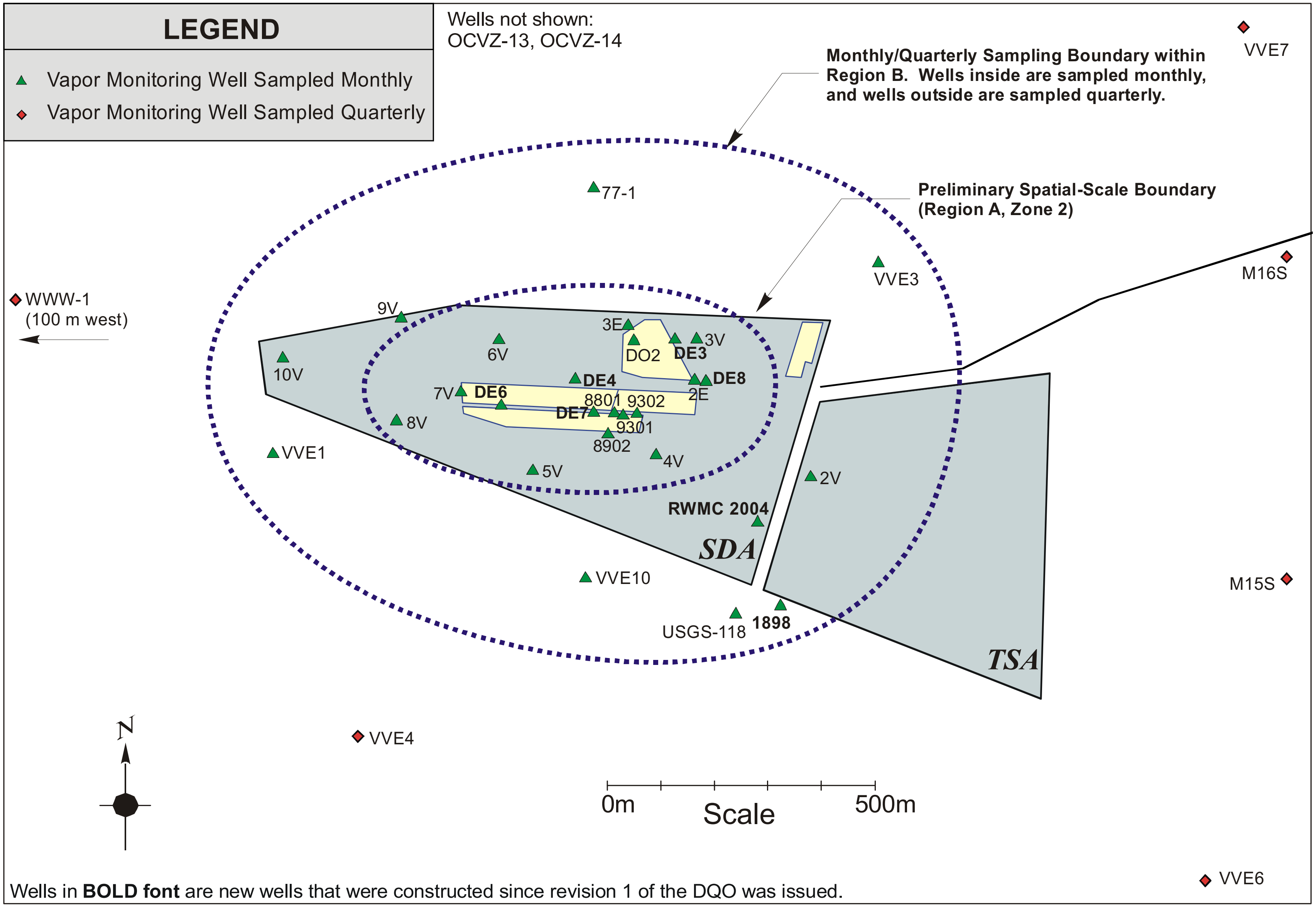


Figure 7-2. Organic contamination in the vadose zone intermediate vadose zone vapor monitoring wells.

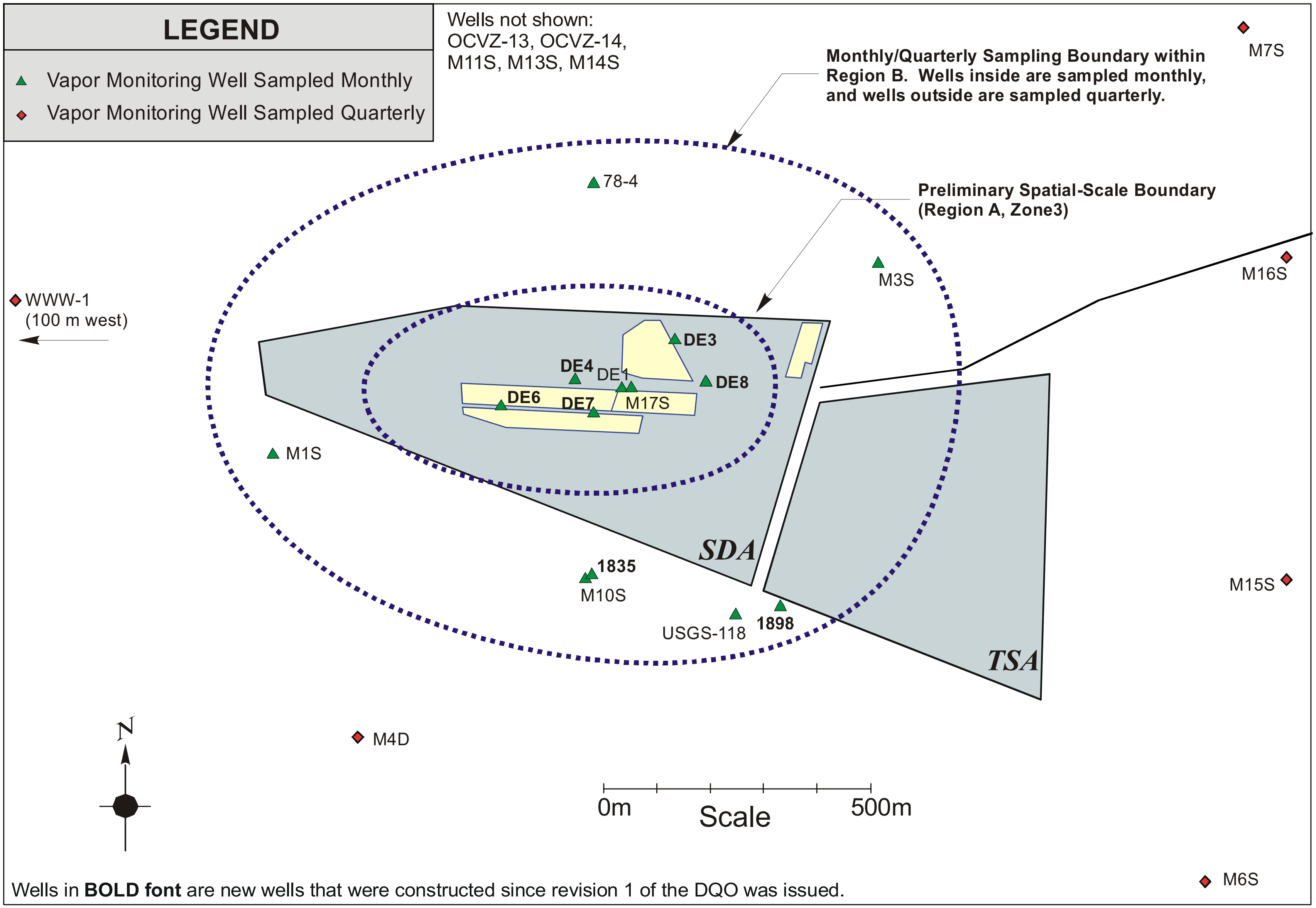


Figure 7-3. Organic contamination in the vadose zone deep vadose zone vapor monitoring wells.

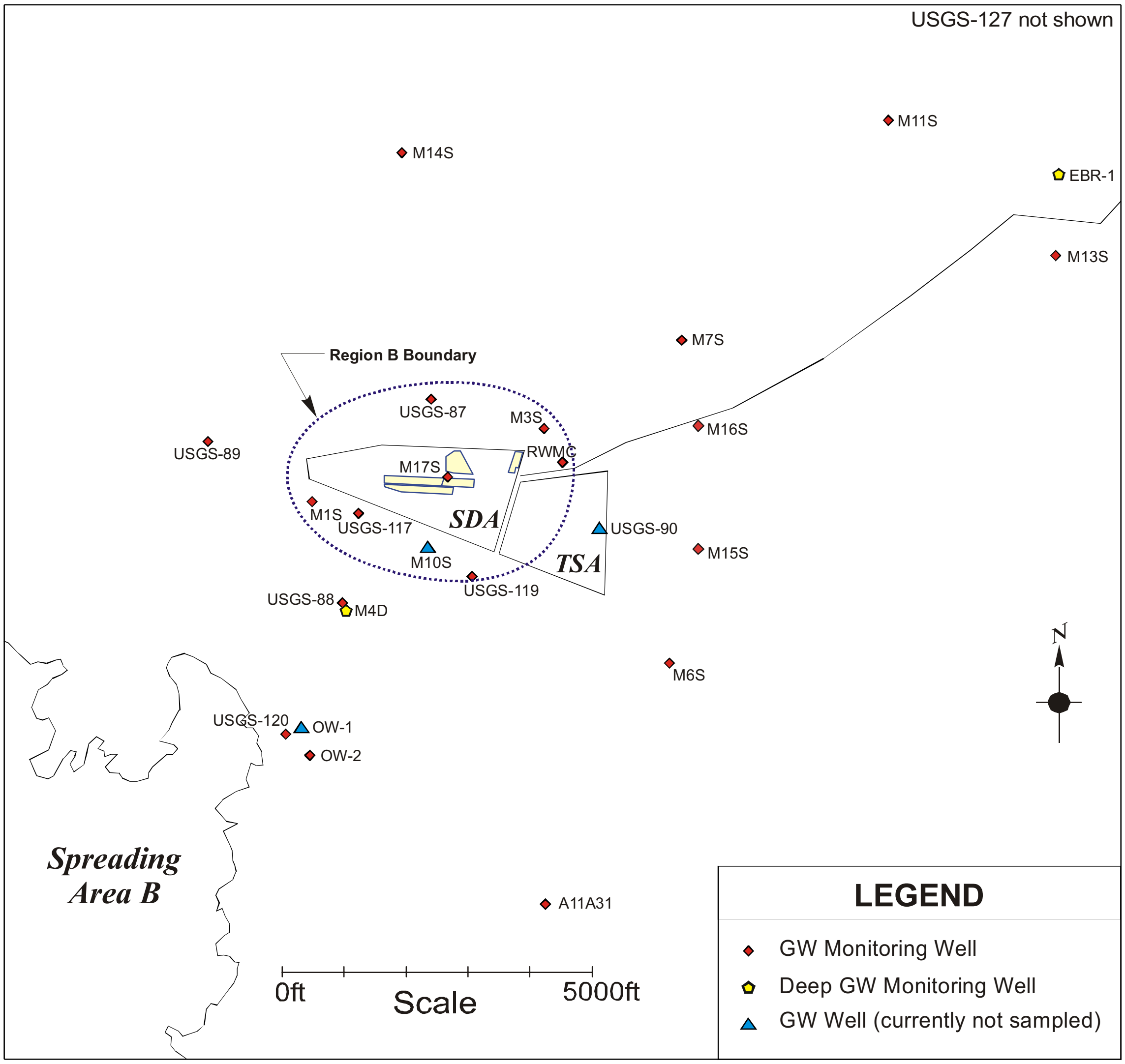


Figure 7-4. Organic contamination in the vadose zone groundwater monitoring wells.

7.4.2 Vadose Zone and Groundwater Monitoring

Monitoring will be performed on a monthly or quarterly basis from extraction wells, groundwater monitoring wells, and from vapor sampling wells. Vapor samples will be analyzed at the on-Site laboratory using the Brüel and Kjær multi-gas, photoacoustic instrument during the initial monitoring, before the vapor concentrations reach the RG values. However, when the 95% UCL of the mean, lognormal mean, or median (as appropriate) vapor concentration of all sampling locations within the RG zone is less or equal to the RG value for that zone, the samples should be sent to the INL Environmental Chemistry Laboratory or to an off-Site laboratory for sampling with full quality assurance/quality control protocols to support the VVET system shutdown decision. One full year of collecting quality-controlled data is planned to support the shutdown decision.

Compliance Verification Phase Sampling—Sampling performed during the compliance verification phase will be used as input for the fate and transport model and to develop control charts for the individual sampling locations. Sampling data obtained during the compliance verification phase will be plotted on the control charts and compared to upper and lower warning and control limits. Monitoring during this period will be performed on a monthly basis. Although one full year of collecting quality-controlled data is planned to support the final shutdown decision, the control charts will be updated as the monthly data is collected.

Long-Term Monitoring Phase Sampling—Successful resolution of the compliance verification decision rule allows the OCVZ project to begin the long-term monitoring phase. This is very similar to the compliance verification phase, except that the project will evaluate mothballing of the VVET units. In addition, the sampling frequency will be reduced to semiannual monitoring.

If semiannual sampling results fall within the control limits defined for all locations for three successive years, sampling frequency will be reduced to a single annual event per location.

7.5 Observations and Recommendations

7.5.1 Remedial Action Considerations

The sampling design developed in this DQO does not formulate remedial action decisions. However, the information assembled in the DQO process may support remedial action decision-making. One remedial action is recommended for consideration by the project team:

- **Further Study and Monitoring of Impacts from Spreading Area Water**—The spreading area waters may create anomalous conditions within the vadose zone leading to VOC contamination of groundwater outside the area of influence of the VVET system. These impacts could adversely affect the OCVZ project's ability to satisfy the RAOs. However, the adverse impacts must be weighed against any potential benefits when considering the fate of the spreading areas.

  Recommendation: If upgradient VOC concentrations exhibit rising trends over time, steps should be considered in the next update to the DQO to improve the conceptual model. Potential impacts from spreading area water on subsurface VOC migration and dissolved phase contaminant migration could be further studied through tracer tests and continued monitoring. Any decisions to alter or relocate the spreading areas should involve OU 7-08, OU 7-13/14, and Agency personnel.

7.5.2 Buried Waste Inventory in the Subsurface Disposal Area

The buried waste in the SDA contains volatile organic contaminants that may present a long-term source of contamination and could impact shutdown of the VVET system. This issue was addressed to the extent possible in Decision Rule 1 and was identified as a global issue because it is beyond the scope of the OCVZ project. A study by Sondrup et al. (2004), as well as other data, indicates that the remaining VOC waste in the source pits could prevent the shutdown within the expected operational period. This issue should be reevaluated after the ARP (see Section 1.6.5) is complete with all planned activities.

7.5.3 Periodic Review of Data Quality Objectives

The OCVZ project is complex, relying on vapor monitoring and fate and transport modeling results to predict the potential to contaminate groundwater after a 100-year institutional period. The dynamics associated with VVET operations, changes to the buried waste status, spreading area water influences, modeling developments, or other factors likely will affect decision-making requirements in the future.

Recommendation: The DQO decision-making requirements for this project should be reviewed periodically for relevance.

7.6 Commitments

Commitments in this DQO Summary Report are compiled below.

1. Carbon tetrachloride will be used as an indicator for TCA, TCE, and PCE; however, the other contaminants will be modeled as well (see Tables 1-5 and 5-5).

2. The control chart limits (see Appendix B) will be based on observed data by the OCVZ project technical representatives using data obtained during the VVET operational and short-term shutdown periods. The number of short-term shutdown periods necessary to establish control chart limits will be determined by the project as the VVET operations database is established.

3. The vapor monitoring data associated with wells inside the SDA will be subjected to a statistical evaluation to enable determination of the spatial scale of decision-making boundary line for all Zones in Region A.

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Appendix A

Statistical Trend Discussion

Appendix A

Statistical Trend Discussion

TREND TESTS

Statistical tests for temporal trends are extremely useful in a number of circumstances. Conventionally, they have been used to establish that a baseline case of observations exhibits no increasing or decreasing trends over the period of record. The lack of trends is a critical assumption to be tested if the base data are to be used to establish control limits against which future observations are to be tested. A minor variation on this application tests for change over time; as in, to determine whether a remedy is significantly affecting well conditions. The following describes the Kendall test. Demonstration of how the statistic is derived displays the sorts of considerations to be taken into account when testing for trends.

KENDALL TEST FOR TREND

The Kendall test is an overall test for trend in a sequence of observations that is nonparametric (i.e., it does not depend on the underlying distribution of data). How the Kendall test is constructed is shown schematically in Figure A-1. A sequence of nine chloride measurements, designated X_1–X_9, in a well over the 2-year period, October 1995 through October 1997, is displayed in the figure.

Kendall Test

The Kendall test generates all possible differences between pairs of sequential observations. For example, the chloride concentration from the first sampling event is subtracted from the level measured from the second sampling event. As indicated in the figure, the difference between X_1 and X_2 is positive (increasing), as is the difference between X_2 and X_3. Conversely, the difference between X_7 and X_8 is negative. (Note that the *relative magnitude of the difference* is not considered. Any difference, large or small, is assigned either a positive or negative direction.) In the Kendall test, the probability of the total number of increases, given the (n)(n-1)/2 possible pairs of data (X_j - X_i, where i is less than j) is found, *assuming* that positive and negative differences are equally likely. In the case of the data displayed in Figure A-1, the probability associated with the Kendall statistic is 0.25, meaning that the cumulative count of positive differences is not significantly higher or lower than expected if the probability of positive and negative differences were the same. One advantage to the Kendall test is the number of degrees of freedom (based on the same sample size), given the calculation of the n(n-1)/2 possible differences.

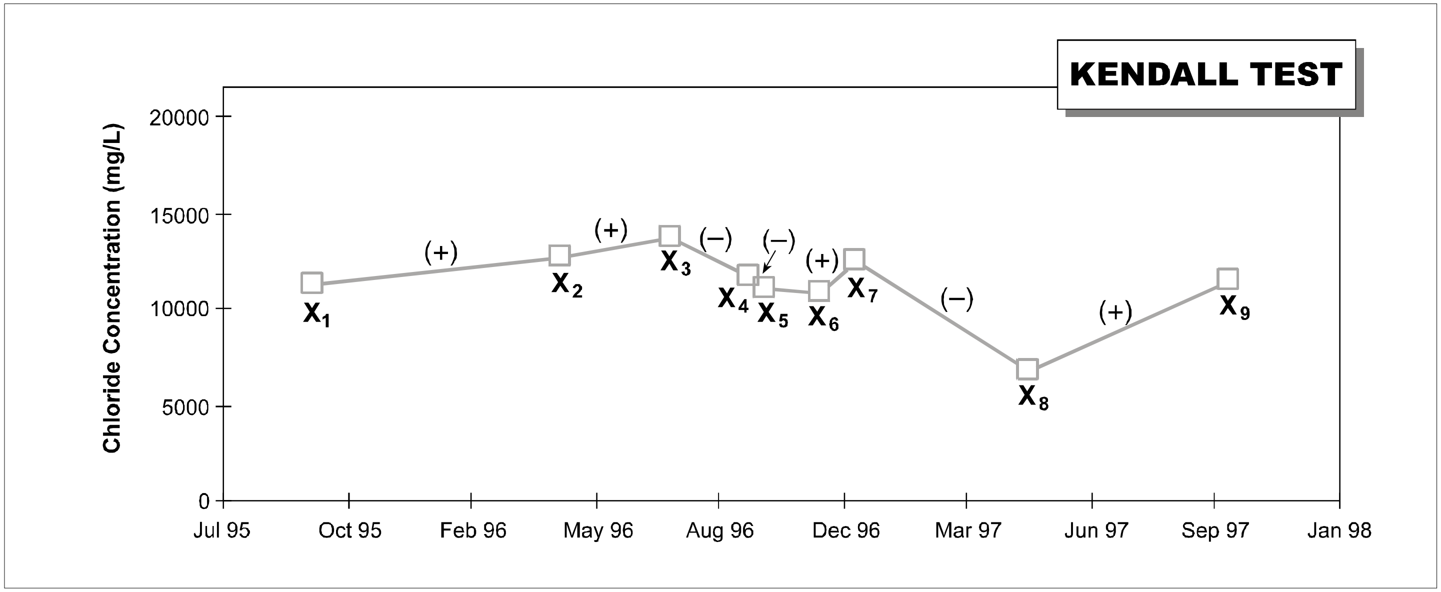

Figure A-1. Example of Kendall trend tests.

Appendix B

Control Chart Discussion

Appendix B

Control Chart Discussion

STATISTICAL CONTROL CHARTS

Control charts are statistical and graphical tools used to evaluate changes in water quality within individual wells over time (EPA 1992, 1989). Intra-well comparisons compare current observations with historic background data from the same well. The method is well suited to document changes following remediation, assuming knowledge of preremediation levels and documenting that remediation goals previously attained are not trending in an upward direction. For example, in the case of an effective remediation project, which has been designed to reduce contaminant levels in groundwater, a hypothetical control chart would be expected to look like the following as presented in Figure B-1.

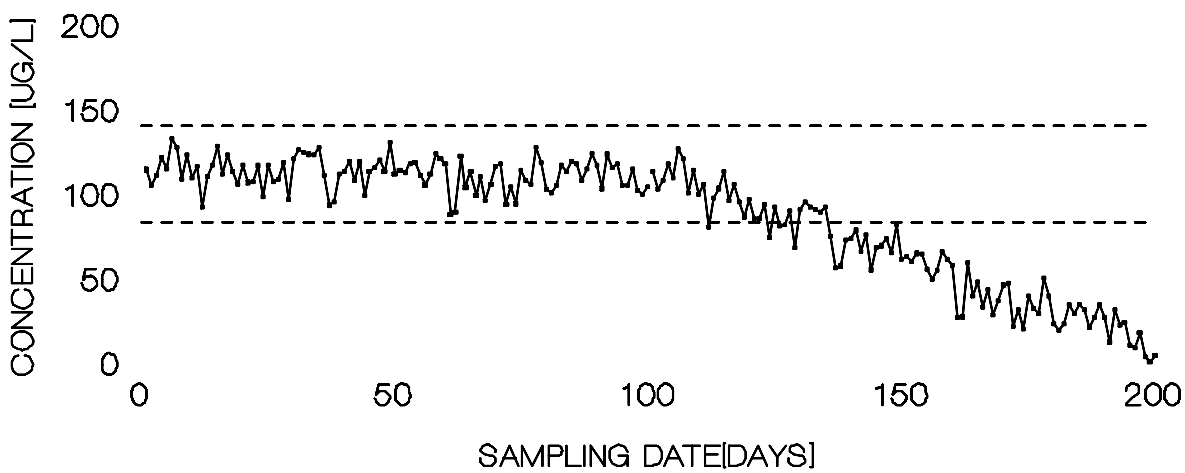

Figure B-1. Hypothetical control chart.

Constituent concentration is plotted on the y-axis and time on the x-axis. The broken lines exhibit control limits, which have been calculated from historic or preremediation data. The control limits specify the range of concentrations expected, with a prespecified level of confidence, assuming no change in constituent levels in groundwater around the well. Sample results falling outside the limits indicate changes with respect to previous conditions. In the above plot, a statistically significant reduction in concentration levels has occurred at time $t_{\sim 100}$. At time $t_{\sim 125}$, measured concentration levels fall below the lower limit, indicating that parameter levels are significantly different from previous levels.

Alternatively, if the control chart were designed to document that remediation goals, which have been achieved, are not changing following shutdown (such as vapor extraction systems), control limits would be developed from a "baseline" period. The baseline is the period over which levels either were exhibiting an ongoing flat or decreasing trend, and when levels (or an appropriately defined statistic such as the UCL) are less than the remediation goal. In this case, the control chart would be documenting adherence to the limit and would be used to document any recurrence of measured concentrations above the baseline period levels.

Development of well-specific control charts depends on the number of available data and parameters being monitored, all underlying distributions of the parameters being measured, the level of confidence desired, and the type of change anticipated. Effectiveness of change detection varies among types of control charts (Montgomery 1991). For example, CUSUM (Cumulative Sum) and exponentially weighted moving average charts are typically better at detecting small shifts in mean value as compared to a conventional mean control chart. Specific features, which are considered during the development of parameter and well-specific control charts for existing and new wells around a particular site's compliance points, include the following:

- **Normality of data.** Control charts assume normal distribution of data. If data are not normally distributed, an appropriate transformation will be determined and the control chart will be developed in that measurement space (e.g., log space for lognormally distributed data).

- **Sample size.** A minimum of 8 to 12 observations is required for each parameter and well, with marked preference for the larger number. In addition, sampling should cover a period over which seasonal or annual oscillations would be covered.

- **Frequency of sampling.** The objective is to define a sampling interval that is frequent enough to detect changes, but not so frequent as to result in observations that are not independent measurements. Monitoring data collected since the installation of the extraction system will be used to optimize sampling frequency from existing and new installations.

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Appendix C

Methodology for Determining Vadose Zone Vapor Concentration Remediation Goals

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Methodology for Determining Vadose Zone Vapor Concentration Remediation Goals

INTRODUCTION

The original preliminary remediation goals (PRGs) provided in the Operable Unit (OU) 7-08 Record of Decision (ROD) (DOE-ID 1994) were developed for the shallow vadose zone (above the 240-ft [73 m] C-D interbed) using the PORFLOW simulation code and a relatively simplistic model. Since the ROD was issued, a more robust, multidimensional, multiphase model using the TETRAD simulation code has been developed to simulate organic contaminant migration in the SDA subsurface. This newer model has been updated and calibrated multiple times to include the latest characterization and contaminant data.

During the writing of the original OU 7-08 Data Quality Objective (DQO) report (Bauer and Ovink 2000), there existed a general consensus among decision-makers and project personnel that the original PRGs should be updated using the TETRAD model. In addition, decision-makers also agreed that PRGs be developed for the deep vadose zone because modeling performed by Sondrup (1998) using the TETRAD model predicted that the portion of the VOC plume below the 240-ft (73-m) C-D interbed was sufficient to cause groundwater concentrations to exceed maximum contaminant levels after the 100-year institutional control period.

PURPOSE

The purpose of this appendix is to present the methodology and results of an effort to determine new PRGs for OU 7-08, organic contamination in the vadose zone (OCVZ). The PRGs support decision-making activities as outlined in the OU 7-08 DQO Summary Report.

PRELIMINARY REMEDIATION GOALS DEVELOPMENT

Simulation Code

The TETRAD code (Vinsome and Shook 1993), Version 12.7, was used to simulate water and contaminant movement using the model described below. The TETRAD code has complete multiphase, multicomponent simulation capabilities and can simulate the behavior of any number of components in aqueous, gaseous, and oleic phases.

Model Description

The model used to determine PRGs was derived from a model presented in Magnuson and Sondrup (1998), which was used to support the OU 7-13/14 Interim Risk Assessment (Becker et al. 1998). Since that time, the model has been revised and improved several times. The latest version of the model is documented in the OU 7-13/14 Ancillary Basis for Risk Assessment (Holdren et al. 2002). The most recent updates to the model will be documented in the OU 7-13/14 Remedial Investigation Report scheduled for publication in 2006. For brevity, this report will present only the most salient features of the model.

The model consists of separate three-dimensional representations of the vadose zone and aquifer. The vadose zone and aquifer model domains are shown in Figure C-1. The aquifer domain is 76 m thick and refined around the SDA to match the base grid of the vadose zone domain. Two levels of grid refinement have been assigned in the vadose zone domain to better represent source locations and interbed lithology. Figure C-2 shows the horizontal grid of the vadose zone model domain. In the vertical direction, the first level of refinement extends from land surface to approximately 110 ft (34 m) just below the B-C interbed. The second level of refinement extends to approximately 40 ft (12 m) just below the A-B interbed. It is difficult to show all three grid levels in the vertical direction because the vadose zone uses vertical conformable gridding to represent the interbeds. This is shown in Figure C-3 where the interbeds and basalts are shaded on the base grid.

A list of remaining relevant details of the model is included below. Additional details are included in Holdren et al. (2002).

- The surficial sediments and sedimentary interbeds have spatially variable surfaces and thicknesses. Hydrologic properties of the surficial sediments and A-B interbed are homogeneous. Hydrologic properties of the B-C and C-D interbeds are heterogeneous and spatially variable. Interbeds below the C-D interbed were not included.

- A dual-continua (porosity/permeability) representation of the fractures and matrix was used for the basalt portion of the subsurface in the VOC transport model. The fractured basalt is represented as a high-permeability, low-porosity equivalent porous medium.

- Infiltration inside the SDA is spatially variable and greater than the infiltration outside the SDA. The range of infiltrations rates inside the SDA is 1 to 10 cm/yr while the infiltration rate outside the SDA is 1 cm/yr. For the PRG simulations only, water movement in the vadose zone is steady state.

- The aquifer was modeled using a constant effective depth of 76 m, and a low permeability region exists immediately southwest of the SDA. Water movement in the aquifer is steady state. Possible influences of the Big Lost River and discharges to the spreading areas on water movement in the vadose zone or the aquifer in the immediate vicinity of the SDA are not accounted for.

- Carbon tetrachloride can exist simultaneously in multiple phases. Interphase mass transfer is linear and reversible. Sorption was minimal in the fractured basalt portion of the vadose zone and was not included in the aquifer model. Contaminant degradation was not included.

- Aqueous-phase carbon tetrachloride migrates with infiltrating water following established flow paths. Gaseous phase movement of carbon tetrachloride occurs by diffusion and by advection. Gaseous advection is controlled by density gradients and pressure gradients.

Methodology

As discussed in the DQO report, the point of compliance is the point or points where the cleanup levels are established. From a regulatory standpoint, the point of compliance for the OCVZ project is the Snake River Plain Aquifer outside the SDA boundary. However, organic chemical concentrations in groundwater cannot serve as a direct indication that the VVET systems may be shut down because of the time delay for the contaminants to migrate from the vadose zone into the groundwater. Therefore, the project will establish remediation goals in the vadose zone in the form of vapor concentrations. Modeling will be the link to establish allowable vapor concentrations such that maximum contaminant levels in the SRPA outside the SDA are not exceeded.

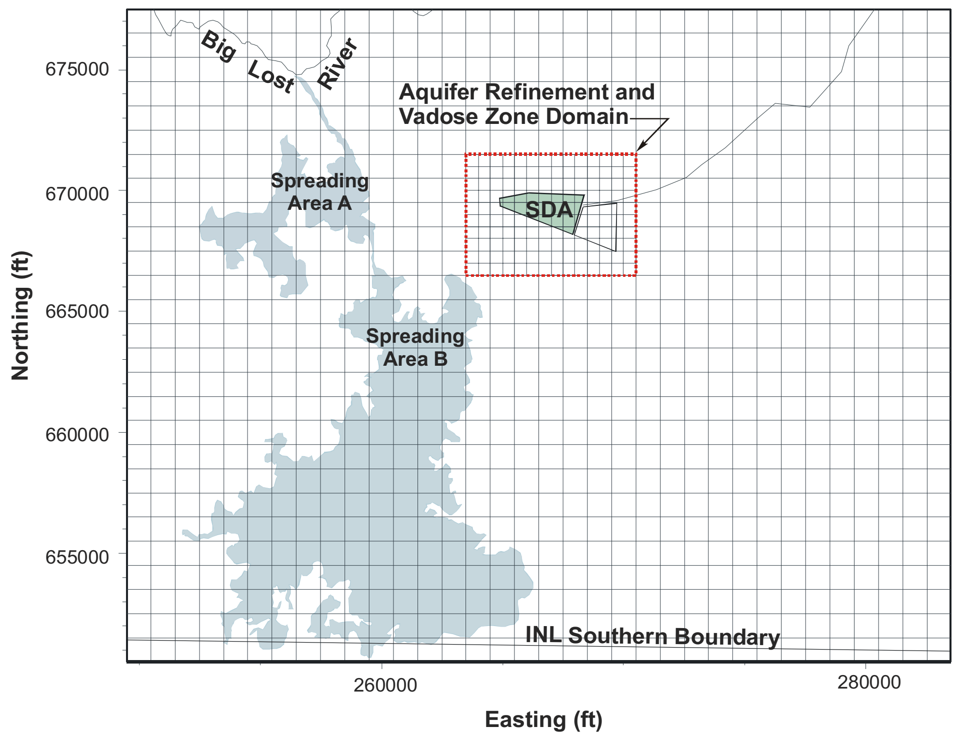

Figure C-1. Aquifer and vadose zone model domains. The refined area of the aquifer grid is the same as the base grid of the vadose zone domain.

Figure C-2. Horizontal base grid and refined grids of the vadose zone model domain.

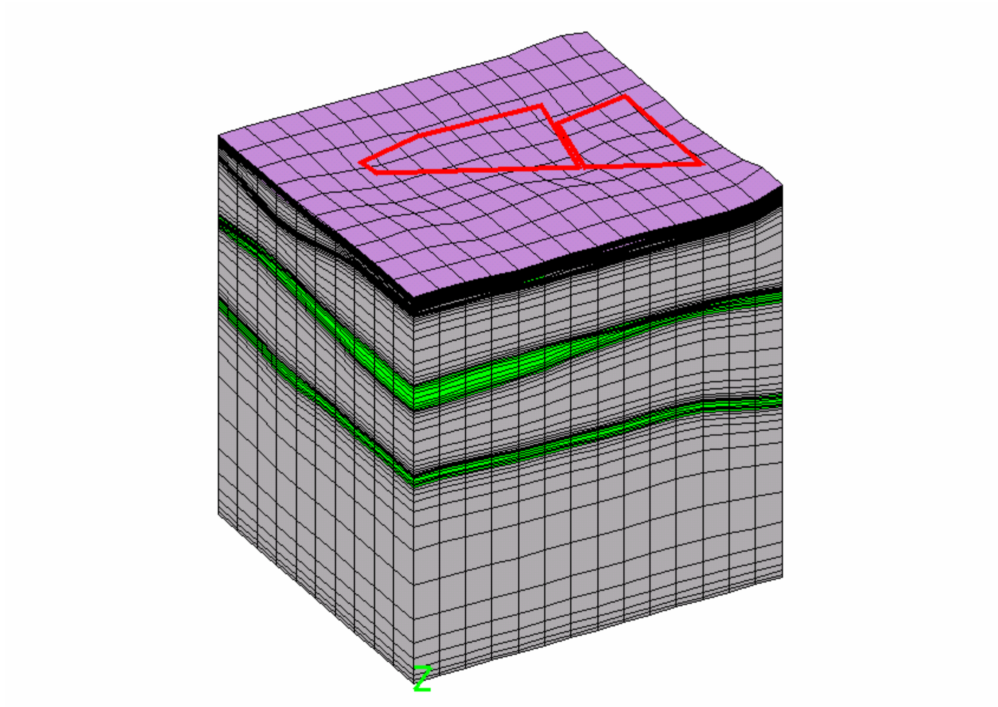

Figure C-3. Southwest view of the vadose zone base grid showing the vertical conformable gridding. Interbeds are shaded green and basalt is shaded gray. The first and second levels of refinement are not shown.

In the original DQO report, three distinct vertical zones in the subsurface were identified based on their potential to contaminate groundwater. Zone 1 is located between the base of the surficial sediments and the 110-ft (34-m) B-C interbed. Zone 2 is located between the 110-ft (34-m) B-C interbed and 240-ft (73-m) C-D interbed, and Zone 3 is located between the 240-ft (73-m) C-D interbed and the water table. Zone 1 has the highest contamination levels, but the least potential to contaminate groundwater, while Zone 3 has the lowest concentrations, but highest potential to contaminate groundwater because it is closest to the aquifer. The subsurface was further divided horizontally into two regions: Region A within the influence of the VVET system, and Region B which is outside the influence. The original DQO specified that PRGs be determined for all three zones of Regions A and B.

Figure C-4 shows the current boundaries of Regions A and B from the DQO report (see Figure 7-1) overlayed on the horizontal model grid. The shaded areas are Regions A and B as represented in the model. The regions were represented as rectangular-like figures in the model purely for convenience. Figure C-5 shows conceptually what the zones of the two regions might look like in cross-section.

The procedure for establishing PRGs was to determine the allowable vapor concentration of carbon tetrachloride for each zone such that the MCL would not be exceeded in the aquifer. To do that, the vadose zone model was run using the prescribed infiltration rates until a steady condition was reached. At that point, the gaseous concentration of carbon tetrachloride everywhere in a particular zone was set to a constant non-zero value, and then carbon tetrachloride was allowed to migrate away from the zone out into the vadose zone. The water and contaminant fluxes out the bottom of the vadose zone domain were input to the aquifer model and corresponding concentrations in the aquifer were recorded. In particular, the maximum concentration in the aquifer at any location outside the SDA boundary was recorded. The

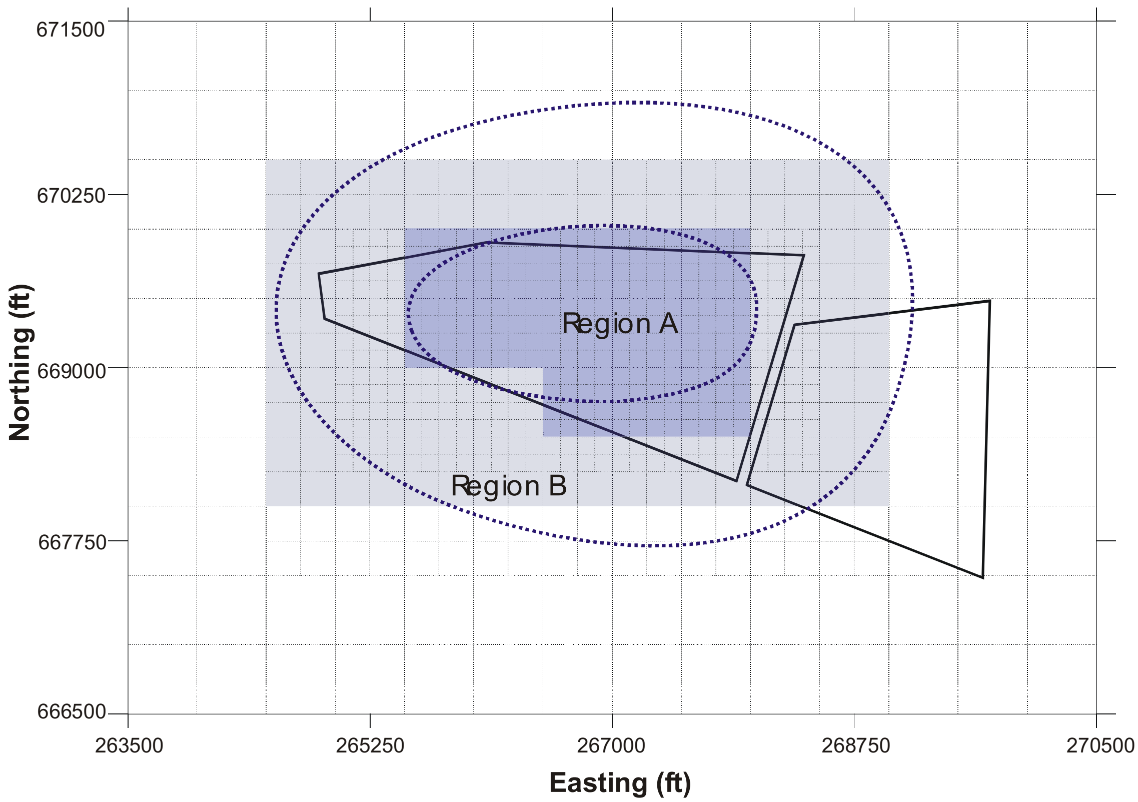

Figure C-4. Locations of Regions A and B as defined in the DQO report (dashed lines), and as represented in the model (shaded areas).

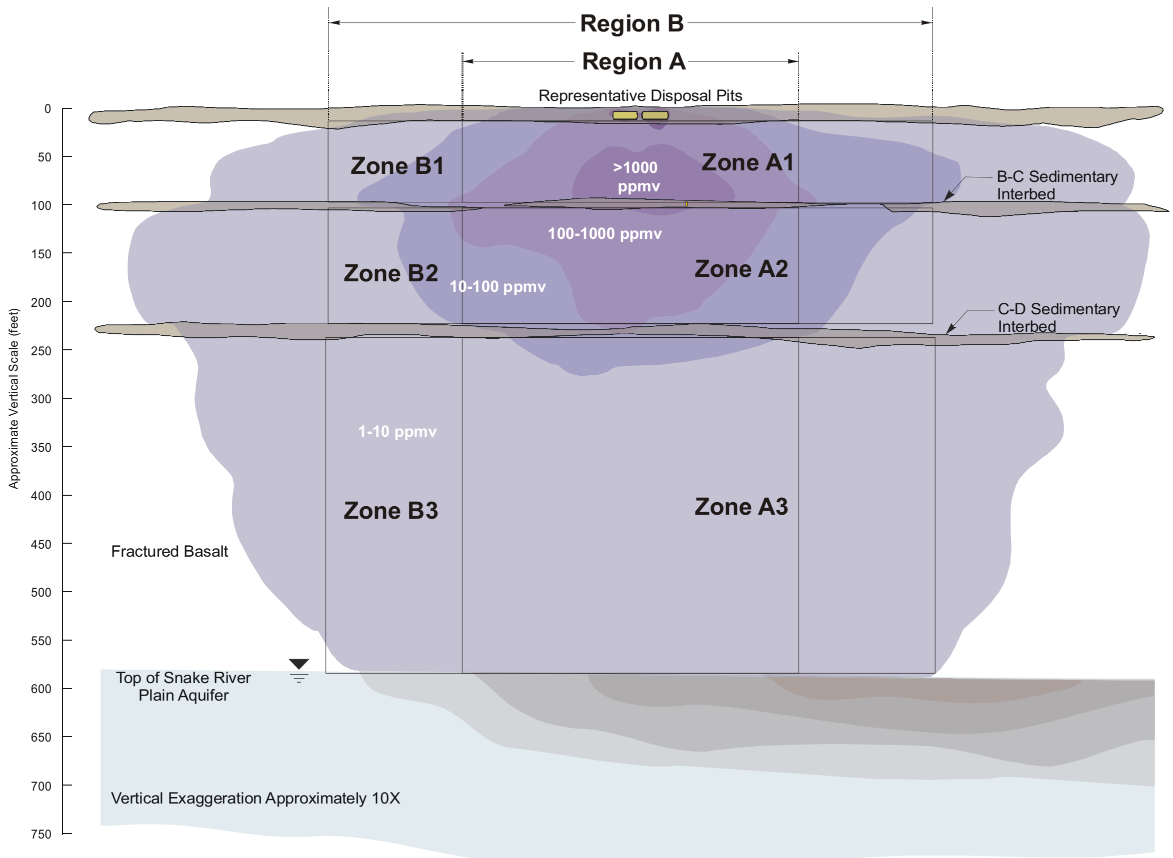

Figure C-5. Cross-sectional drawing of the carbon tetrachloride vapor plume showing the zones of Regions A and B. The shape and concentrations of the plume are approximate, based on data collected before operation of the VVET system began.

allowable vapor concentration or PRG for that zone is then the ratio of the MCL to the maximum predicted aquifer concentration, multiplied by the constant vapor concentration assigned to the zone. This procedure was then repeated for the other zones. The results can be scaled in this fashion because of the linearity between the assigned vapor concentration and the aquifer results.

In the model, the mass dissipates relatively rapidly from each zone because of the initially “clean” vadose zone surrounding it. It is more likely that the concentration in a particular zone will remain relatively constant as the actual concentration approaches the PRG from a contaminated vadose zone condition. Therefore, a second set of simulations were performed in which the vapor concentration in a particular zone was set and held constant (fixed) for a particular period of time. The length of that period was the time required for an amount of mass equal to the initial mass in the zone (determined by the concentration, porosity, moisture content, etc.) to be transported out of that zone. At that point, the concentration was no longer held constant and the simulation was allowed to proceed. The length of time the concentration had to be held constant was determined by keeping track of the mass that crossed the zone boundary into the vadose zone during the simulations in which the concentration was initially set, but not fixed. Figure C-6 is a simplified drawing of how the vertical vapor concentration profile will change with increasing time if the concentration is set and released, or set and held constant.

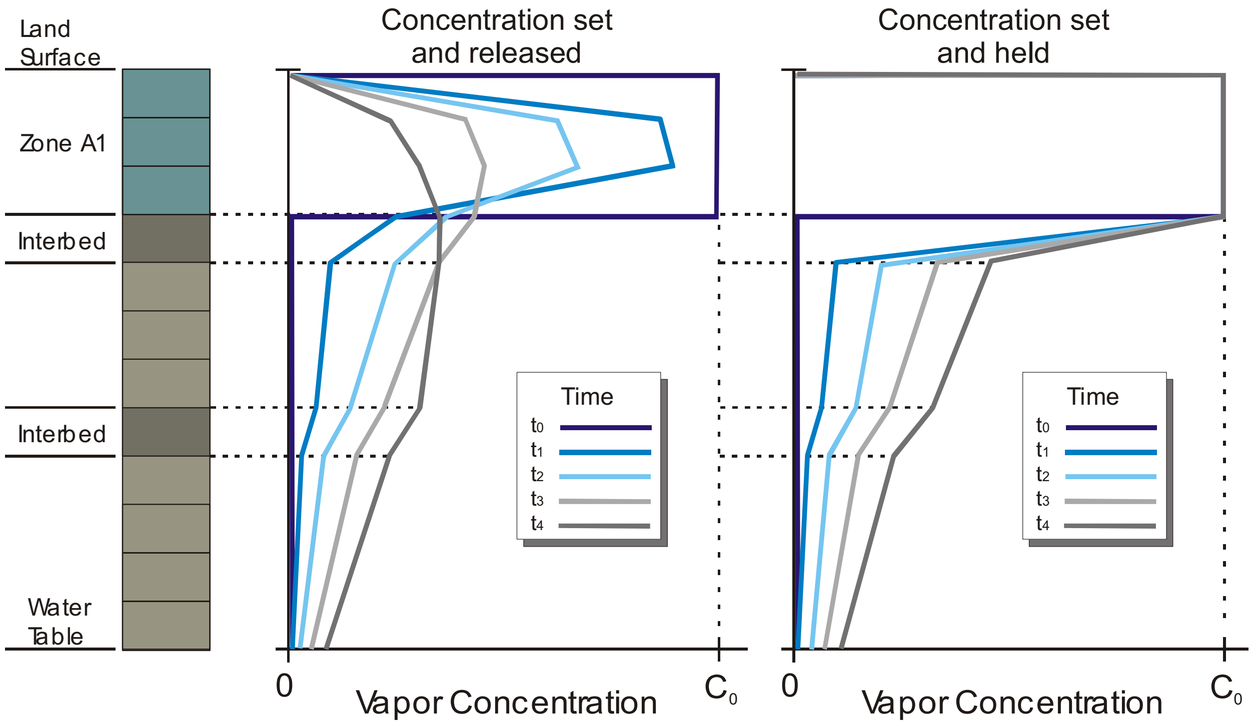

Figure C-6. Simplified illustration of how the vertical vapor concentration profile changes with time if the concentration is set and released, or set and held constant. Zone A1 is used as an example.

Results

Table C-1 contains the PRG results for carbon tetrachloride for each of the three zones in Regions A and B. The larger number is for the case when the concentration was not fixed. This is called the 1×result because only the original mass (1×) was allowed to cross the zone boundary. The smaller number is for the case when the concentration was held fixed until the mass crossing the zone boundary was equal to the original mass. This result is called the 2× result because twice (2×) the original mass was put into the model, the original mass plus an equal amount that was allowed to cross the zone boundary while the concentration was held fixed. Figure C-7 shows the predicted maximum aquifer concentrations outside the SDA boundary for the 2× PRG values in Table C-1. The shapes of the curves are not smooth because the location of the maximum concentration changes with time. Figure C-8 shows the PRG results on the drawing of the subsurface cross-section.

Table C-1. Preliminary remedial goal results for carbon tetrachloride based on 1× and 2× mass multiples.

PRG Zone	Estimated PRG Based on 1× (ppmv)	Estimated PRG Based on 2× (ppmv)	Number of Years Concentration Held Fixed for 2×
A1	190	118	0.5
A2	39	20	2.7
A3	6.5	3.3	15.6
B1	50	32	0.6
B2	11	5.6	2.5
B3	1.4	0.9	28.4

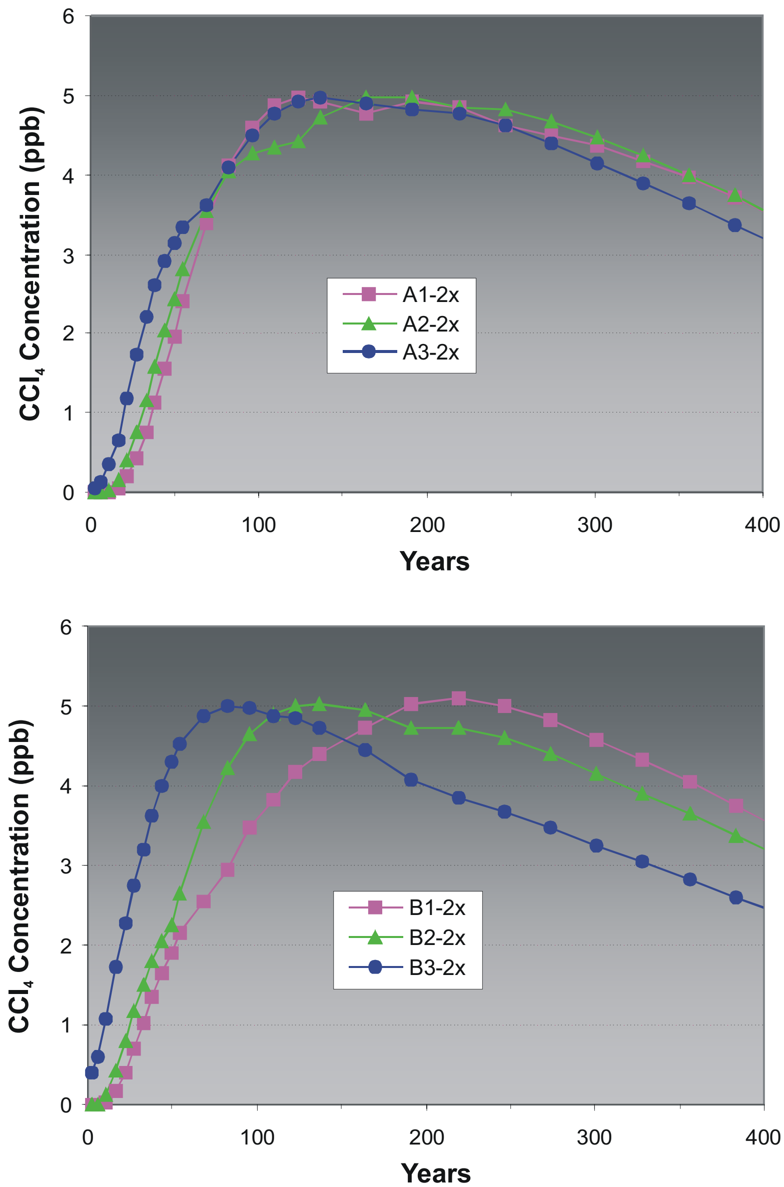

Figure C-7. Maximum predicted carbon tetrachloride concentrations in the aquifer outside the SDA boundary for Regions A and B, Zones 1 through 3, using the 2x PRG values in Table C-1.

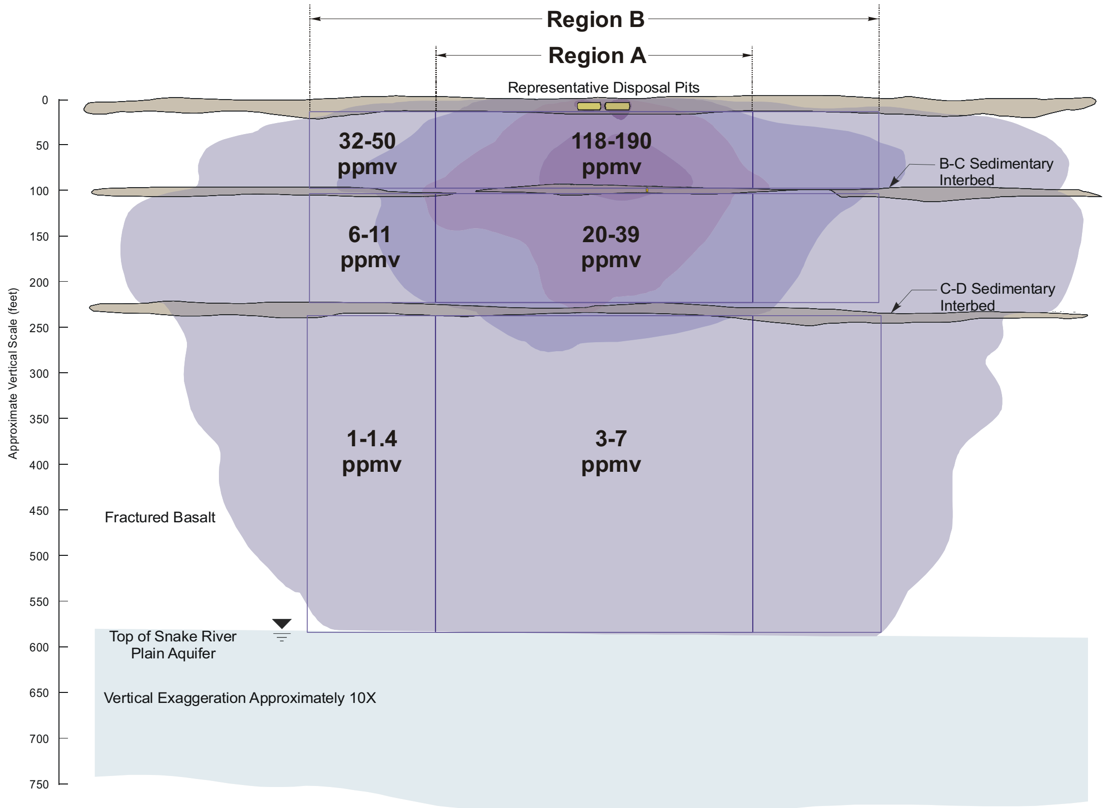

Figure C-8. Cross-sectional drawing of the SDA subsurface showing the PRGs for each zone.

The aquifer concentrations used for the PRG determination were taken from the second grid block below the water table in the model. This is consistent with the strategy outlined in the Track II Guidance (DOE-ID 1994), OU 7-13/14 Interim Risk Assessment (Becker et al., 1998), and Ancillary Basis for Risk Assessment (Holdren et al., 2002). The second grid block is used because it is assumed that a receptor would place the well screen approximately 15 m below the water table. If the results from the top layer of the aquifer model were used, the PRG results would be about 5 to 10% less.

The PRG simulations were also run without atmospheric pressure fluctuations, or sometimes called barometric pumping. This was done as a matter of convenience. The VOC transport model was calibrated using a simple square-wave approximation of average barometric pressure changes, but barometric pumping causes very long simulation times because the time step is limited by the pressure changes. Simulation times are on the order of a few days without barometric pumping, compared to several weeks with it. A single simulation was run with barometric pumping, and the results indicate that including barometric pumping would reduce the PRG results by about 5 to 10%.

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